Manitoba

Jack Pine Budworm Information Exchange

January, 1986
Winnipeg, Manitoba

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Manitoba

Natural Resources

June 30, 1986

Forestry Branch,
Forest Protection
300-530 Kenaston Blvd.
Winnipeg, Manitoba

Dear Participant:

Sharing information, experiences and knowledge is the most direct means to reach our goal of understanding and reducing the jack pine budworm problem. This was the philosophy behind the two-day seminar we held in Winnipeg in January, 1986.

On behalf of all those involved, I would like to thank the participants from Canadian and American federal forest agencies, provincial and state forest agencies, industry and those from universities who have been, or who currently are, involved in the research and control of jack pine budworm.

I am sure all who attended would agree that the presentations were well done, the information valuable and that the workshops provided the opportunity to actively discuss much of the information we had heard in the previous day and a half. I hope all of you have or will follow through on your commitment to continuing the information flow from one agency to another.

Attached are the papers presented at the jack pine budworm workshop. Copies of this report have been sent to all participants as well as those who were invited but were unable to attend. I would like to thank you again for your participation, in what I perceive to be an ongoing information exchange.

Respectfully submitted,

Geoff Munro (Chief)
Forest Protection
Manitoba Natural Resources

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Jack Pine Budworm Research and Implementation

in the

Michigan Cooperative Forest Pest Management Program

by
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*Jack pine, **Pinus banksiana** lamb., and red pine, **P. resinosa** Ait., are the dominant pine species in Michigan, Minnesota and Wisconsin. Jack pine, which occupies 992,000 ha (Benzie 1977), covers more than twice the land area of red pine in these three states. Jack pine budworm, **Choristoneura pinus** Freeman, is the most economically important of some 58 insect species that utilize jack pine (Howse 1984).*

In Michigan jack pine budworm exhibits outbreaks at eight to 15 year intervals. The most recent outbreak in the lower peninsula was the most severe on record for Michigan (Murray 1981-82). In 1981 551,000 acres were defoliated and in 1982 this increased to 624,464 acres. In 1982, 348,798 acres were expected to exhibit 35 per cent tree mortality, while living trees were expected to exhibit 90 per cent growth loss. Currently, this outbreak has subsided and high populations of the insect are confined to a very small area (less than 10,000 acres). The budworm, however, appears to be on the increase in a number of locations in the upper peninsula (Heyd, personal communication).

For the past several years members of the Michigan Cooperative Forest Pest Management Program (Wilson et al. 1983) have been developing and utilizing population monitoring and prediction methods, biology/population dynamics studies, computer-based economic decision support tools and have strived to implement an integrated pest management program. This paper will attempt to summarize the development and implementation that has taken place.

Budworm Population Monitoring Techniques

Egg Mass Sampling

For the past four years G. W. Fowler of the University of Michigan and G. A. Simmons of Michigan State University have been researching egg mass sampling of jack pine budworm in an effort to offer improvements in much the same manner that they attempted to do with spruce budworm egg sampling (Fowler and Simmons 1985). To date they have completed field work and data analysis but have not yet published any of their findings. Preliminary results, however, are as follows:

1. Regression equations for number of eggs per egg mass based on length have been developed for two row, three row and two row with a partial third row.
2. The most consistent measure of foliage on a branch is the "grid method" which requires cutting branches into five to 15 cm segments and loosely arranging the segments over a gridded surface.
3. The least biased sample unit is a full-length foliated branch.
4. The "optimum" sample will likely be two full-length branches, one taken from the lower third of the live crown and the second taken from the middle third of the live crown.
5. The physical arrangement of clusters of sample units has yet to be worked out.

Overwintering Larvae Samples

During the peak of the jack pine budworm outbreak

in the lower peninsula, A. L. Eavy and G. A. Simmons of Michigan State University developed and utilized a "soda wash" technique for measuring overwintering larval densities. Briefly, the technique is similar to that used for the spruce budworm (Miller and McDougall 1968, Miller et al. 1971, 1972, Trial 1984). The basic method, once branches are obtained, involves seven steps:

1. Branch samples are cut into pieces (approximately five cm long) and placed in a three gallon plastic bucket.
2. Eight quarts of hot tap water and 151 g of reagent grade sodium hydroxide pellets are added to the bucket.
3. The mixture is stirred for 20 seconds every 15 minutes for about four hours.
4. The solution is poured through a graded series of soil sieves to remove the branches and other debris.
5. The liquid is placed in a large separatory funnel and hexane is added to the top of the solution.
6. The sodium hydroxide solution is withdrawn from the separatory funnel leaving second stage larvae in hexane. The hexane and larvae are filtered through a Buchner vacuum funnel.
7. The larvae contained on the sample branch are now on filter paper and are counted under a dissecting microscope.

In general, the laboratory process was slightly easier than that for spruce budworm on either spruce or fir branches. The primary reason for this is that jack pine branches generally contain less debris than spruce or fir.

We also briefly explored the correlation between overwintering counts and samples of third and fourth stage larvae taken from the same sample trees the following spring. Correlations were not strong ($r<0.1$) suggesting some additional studies would be necessary to better establish sample unit location, size, etc. Since populations have waned and resources are limited, these studies have not yet been pursued.

Biology/Population Dynamics

The biology of some of the parasites and their hyperparasites was recently investigated by N. C. Elliott and G. A. Simmons. Host-parasite synchrony, spatial and temporal activity patterns of **Glypta fumiferanae** Viereck, **Apanteles fumiferanae** (Viereck) and **A. morrisi** Mason was studied in Michigan's Lower Peninsula. Results of this study indicated that the activity of adult insects varied temporally and spatially in relation to budworm phenology. In addition, activity of adult parasites varied with the time of day, temperature and the vertical stratum within tree crowns. Hyperparasites of **Apanteles** spp. pupae were found to be spatially dependent upon the density of **Apanteles** pupae. Details of these studies can be found in a number of publications (Elliott 1985, Elliott et al. 1986a, 1986b, 1986c).

Computer-Based Economic Decision Support

Impact of Budworm on Economic Returns

A simulation model was developed to evaluate the impact of jack pine budworm on economic returns from jack pine pulpwood and timber production. The simulation model was constructed to pertain to jack pine production in the lower peninsula of Michigan. Stand growth was simulated with a nonlinear deterministic stand growth model based on lower peninsula data. Volume was a function of basal area and height. The jack pine budworm component of the model was generated stochastically to obtain the time interval between outbreaks and to determine the effect of the outbreak on jack pine growth. This was based on about 40 years of data that had been kept by the Michigan DNR. In all instances the optimum rotation ages decreased substantially when the effects of budworm outbreaks were included. Simulations of the economic effectiveness of reducing budworm impact through insecticide application was also investigated by comparing volumes at optimum rotation ages for control and no-control strategies. Since the optimum rotation age is the point where no additional value is added to the stand, the stand with the greatest volume at rotation is the most valuable. Under these assumptions, the simulation indicated that insecticide application was not cost effective because volumes were greater under the no-control strategy. This information has been published and additional information is available in Nyrop et al. (1983).

Banksiana — a Simulation Game

BANKSIANA is a menu-driven program written in p-system Pascal for the IBM microcomputer. Its purpose is to simulate the growth of jack pine stands under different methods of management for insect control and to evaluate those different methods economically. It can be used in a "gaming" mode to help train land managers to anticipate decision-making relative to jack pine or it can be used in an analysis mode to compare the outcomes of different management methods. The insects modeled include the jack pine budworm and the white pine weevil. Control alternatives are limited to determining the timing of

sprays and deciding the type of spray operation to implement. Insect monitoring activities are included in the model as an aid in deciding when to spray.

At the beginning of the program, the user can initiate a stand by any one of several site preparation and planting methods. Once a stand is initiated, the program enters the main phase where tree growth under insect feeding pressures is simulated. During this phase, insect monitoring and control decisions are made by the program user. At the end of the program run, all costs associated with control efforts are discounted to the year of stand initiation and are compared with the discounted value of wood saved to yield a net current value for control efforts. A description of this program has not been formally published but is in preparation from a thesis completed by R. J. Drapek, a student of G. A. Simmons at Michigan State University (Drapek 1985).

Integrated Pest Management Program

Jack pine pest management is conducted within the umbrella of a broader pest management program that has been implemented in Michigan. A forest pest management team was organized in the late 1970's through the co-operation of those Michigan universities with forestry schools, the Michigan Department of Natural Resources and the USDA Forest Service. The goals of the effort were to devise new technologies, transfer available technology, and provide service and management alternatives to foresters in Michigan. The program emphasizes improved forest management rather than pest management alone for the prevention of pest damage and the management of pests. Dissemination of pest management information has been of prime concern resulting in new research results going directly to land managers for immediate use. Among the activities the team participates in are: annual monitoring of pest and stand conditions in pine plantations; forest compartment reviews; development of prescriptions for land parcels; field and classroom training sessions; production of articles, leaflets, handbooks and manuals; the identification of research priorities; and the conduct of field and laboratory research. Services and management recommendations are provided mostly through forest pest specialists located in the field. A number of different publications that pertain to jack pine and the pest management program are cited for your further information (Wilson et al. 1983; Simmons et al. 1982; Mosher et al. 1980).

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Jack Pine Budworm: The Minnesota Situation

by
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In Minnesota there are 505,000 acres of commercial and 211,000 acres of non-commercial jack pine forest land. Jack pine is also a common component of the red pine type on 247,000 acres and of the white pine type on 859,000 acres in the state. The volume of the commercial jack pine type is estimated to be 594,000 M cubic feet.

Prior to 1965, infestation history of the jack pine budworm in Manitoba was not documented. High budworm populations were recorded during the period of 1965-1969. This outbreak produced scattered top kill and mortality in 1966 and 1967 in west central and northwestern Minnesota. Limited aerial spraying was conducted in 1966, 1968, and 1969 to protect the pine resource surrounding and including the two state tree nurseries and a state forest campground. From 1976 to 1980, heavy defoliation again occurred in west central and northwestern Minnesota. Defoliation levels peaked in 1978 when 68,000 acres were moderately to severely defoliated. In 1981 through 1985, a budworm outbreak in northeastern Minnesota defoliated 2,000 acres. In 1984 and 1985, surveys found budworm infesting approximately 200,000 acres across the major jack pine range. This outbreak again caused moderate to severe defoliation to 5,000 acres in the same areas and stands in west central Minnesota where it occurred during the periods of 1965-69 and 1976-80.

Surveys

The major jack pine areas in the state are surveyed each year for the jack pine budworm. The objectives of the surveys are to detect an increase in the population, to evaluate its intensity, and to assess and predict damage potential. Survey intensities vary with individual infestations. Years with little or no budworm result in dispersed sampling locations that may be one to six miles apart. During infestations, sampling locations are placed ¼ to one mile apart.

For life stage surveys, major emphasis is placed on the early larval survey conducted prior to the fourth or fifth instar. This survey is based on 30 shoots collected from six branches from each of five trees. If possible, the 30 shoots are divided equally between vegetative and staminate shoots. Where possible, collections are made from the ground, and the number of shoots infested with larvae are counted. Individual larvae are not counted. A count of twenty or more shoots infested predict a moderate to severe defoliation potential that means at least 50% crown loss on individual trees.

Egg masses are the focus of the other major life stage survey. This survey is done by collecting two branches from the mid-crown of four trees, one tree from each crown class. Eighteen inches of needle-bearing surface on each branch is inspected for egg masses. An average of one egg mass per tree predicts the potential for moderate to severe defoliation the following growing season. Defoliation predictions from this survey are erratic. Survey results, however, can give an idea of population health by the number of parasitized eggs, indicate egg laying success in a particular location, and reveal new areas of potential budworm activity for the next year. If the egg mass survey is done late enough in the summer so that staminate buds can be detected, a staminate bud survey is also conducted. The percentage of staminate buds on the branch samples is recorded. This provides an idea of food conditions for the next growing season — critical for larval survival.

When high population levels occur, a pupal survey is also conducted. This consists of collecting 25 to 100 pupae per location, and observing emergence. Empty pupal cases are also collected and included in the survey. The percentage parasitism and non-emerging pupae are recorded to look for trends in population health.

Defoliation surveys are conducted both from the air and from the ground. Defoliation is sketched on maps by defoliation classes: light (one to 20 per cent), moderate (21-50 per cent), and severe (51-100 per cent). Aerial surveys are also used to detect the occurrence of budworm feeding and usually are conducted in early July when foliage firing reaches its peak.

During 1985, pheromone trapping was also undertaken on a limited basis. Trap placement consisted of three traps spaced 40 meters apart in a triangular configuration. Each trap had a different lure concentration: .3%, .03%, and .003%. Because this was the first use of these traps in Minnesota, trap catches cannot be correlated with defoliation and population

numbers from early larval and egg mass surveys. It is hoped that pheromone trapping will replace some of the currently used life stage surveys.

Research

In 1984, work began in developing risk and hazard systems. Important factors which influence budworm buildup and damage were identified from field experience and from the scientific literature. An office evaluation was made of jack pine stands using stand inventory data and the identified risk/hazard factors. Field checking a sample of these stands is now being done to assess the capability of the forest inventory data to be a predictor of stand risk and hazard. The long term objective of this approach is to provide land managers with a tool to direct their silvicultural practices. The stands which have the greatest risk of becoming infested with budworm and have the greatest hazard of experiencing top kill and mortality should be given the highest priority for harvesting.

Risk and hazard factors which were identified and used in the stand evaluation process include stand age, basal area, site index, physiographic class, and the basal area of other non-jack pine species mixed in the stand. High risk for each of the factors was identified as follows:

Factor	High Risk
Stand age	Greater than 49 years
Basal area	
Minimum	Less than 70 square feet per acre
Maximum	Greater than 150 square feet per acre
Site index	Less than 55
Physiographic class	Dry
Non-JP species	
Basal area	Less than 40 square feet per acre

Work has also begun on establishing and monitoring a system of permanent plots with the following objectives:

- To refine and validate risk and hazard rating systems
- To assess timber and growth losses during and after an outbreak, and to look for regional differences in impact due to climate, soils, presence of other pests, etc.
- To determine what losses are acceptable, and to develop a threshold for intervention or direct control
- To develop a system to predict the impact of the budworm on a stand based on observed levels of defoliation and stand characteristics
- To refine existing and develop new budworm management practices to be used as a tool by the land manager

Permanent plot work began in 1983 with the initial goal of establishing 80 plots across northern and central Minnesota. At this time, 58 plots are being monitored, and the remainder are expected to be established this year. Plots are established on public lands in areas with an extensive jack pine acreage using a 10-factor prism. Each tree on the plot is numbered, its crown class determined, DBH measured, and the number of growth rings in the outer inch of the tree's diameter counted. Other inventory data collected includes plot and stand basal area, site index, stand age, soil type, and understory vegetation.

Annually on each plot, egg mass and early larval surveys are conducted, pheromone traps are placed, individual tree defoliation is recorded, and weather is monitored. Once survey results reveal that the population has collapsed on a given plot, the inventory data and the impact data will be collected the following year and again two years later.

Control

In managing the budworm, the Minnesota Department of Natural Resources promotes the use of indirect control methods through integration of budworm control strategies into forest management activities. Direct control methods, especially the use of insecticides, are still an option for high value stands. Insecticide use, however, is restricted by political, economic, and environmental considerations.

Budworm control strategies are aimed at minimizing pollen production, and maintaining tree vigor. State, county, private, and industrial landowners and managers are encouraged to use these control strategies in order to minimize the impact of the jack pine budworm on all land ownerships in Minnesota. Recommended strategies include:

a. Maintain an optimally stocked stand to reduce the numbers of wolf and suppressed trees which contribute to a budworm buildup by consistently producing abundant staminate cone crops. Stocking is to be maintained between 70 and 150 square feet per acre of basal area.

b. Favor stands with a site index of at least 55 so that vigorous jack pine stands are being managed.

c. Thin jack pine from below on sites with a site index of 60+ and where economically feasible. Thinning should be done as soon as a commercial sale is possible, and thinning should reduce the basal area to 80 square feet per acre.

d. Remove the wolf trees but give precedence to maintaining the optimum stocking goals.

e. Harvest jack pine between 45 and 50 years of age. Do not try to store jack pine on the stump to regulate the harvest. On only the very best sites, 70+, can jack pine be held longer than 50 years. The poorer the site, the earlier the harvest should be.

f. Break up large, extensive stands of jack pine with two to five chain wide buffer strips, with hardwood stands, or with white spruce or larch plantings.

g. Limit the size of jack pine stands to not more than 40 acres.

h. Harvest high-hazard stands and areas of heavy infestation first.

Surveys Conducted in Northwestern Wisconsin

for

The Jack Pine Budworm, *Choristoneura Pinus* (Freeman)

by
R. B. Stewart

The jack pine budworm has been a serious defoliator of jack pine in the Lake States for many years. Considerable research has been done on the insect and its control in Wisconsin. Numerous species of natural parasites tend to keep the budworm population at endemic levels. Periodically however, populations erupt to epidemic levels and top killing and mortality of jack pine result.

The following surveys were started during the widespread budworm outbreak that ran from 1954 through 1957. Since 1957 most of them have been continued and, where necessary, changes and refinements have been made. Many refinements are still needed, and it is hoped these will come with further experience and research. However, the existing surveys do enable us to predict population trends and indicate areas of potential damage with a considerable degree of accuracy.

The surveys are conducted each year (except prespray counts) at the same locations. These locations are spaced throughout the 300,000 acres of jack pine type in the area. During endemic populations about 100 plots are sampled. When an increase in population is indicated, additional plots are strategically placed in an attempt to delineate the periphery of the outbreak. Currently, about 143 plots are being sampled due to the widespread increase in populations.

Jack Pine Budworm Egg Mass Survey

This survey is conducted in August of every year throughout the jack pine type. It has been somewhat inconsistent, some years giving a good indication of the next generation, while other years results were inconclusive. Experimentation and observation led to the conclusion that weather during the oviposition period was one key factor. Windy weather during that period tends to force the females in closer to the trunk of the tree. Therefore more eggs are oviposited on the inner branches than on the terminals of the branches. Also a large portion of the terminals is made up of new growth and the females rarely oviposit on new needles. Since 15 inch terminal branches were collected, frequently a majority of the egg masses were missed. In 1967 small branches in nearer the tree trunk were collected and these appear to give a much better indication of the population for the following year. In future years the survey will be conducted in the following manner:

Two 15 inch branches (15 inches of needle bearing surface) from each of three trees will be clipped at each spot. These will be taken at mid-crown with a pole pruner and a definite attempt will be made to obtain branches from the inner part of the crown near the trunk. The branches will be fastened together, labeled by plots and brought into the laboratory. They will then be examined for egg masses and the egg masses will be recorded and placed in vials. After eclosion is complete they will be examined and approximate percentage of parasitism will be recorded. Mr. Dan Jennings of the North Central Forest Experiment Station suggested that use of a black light made the egg masses much easier to see. This will be tried next year.

Three egg masses per plot, or .5 egg masses per 15 inch of needle bearing surface is considered as the breaking point. Any area having more than this has a potential for moderate to severe defoliation the following year. The results of this survey are used to designate areas which may have high populations the following year. Plans for possible control can then be prepared.

Jack Pine Budworm Early Larval Counts

This survey is conducted every year and is probably the primary one for indicating the presence of destructive populations. The majority of the larvae break hibernation very near the same time each year. In the past ten years it has taken place between May 24 and June 7. The second instar larvae are extremely small but are active and readily seen by a trained eye. For several years the total number of larvae were counted in each shoot and staminate flower. During high populations the number per staminate flower could reach 30 or more larvae. Counting these was

time consuming, and since only one to three of them usually survive it was felt that the counting time was wasted. In 1967 the decision was made to report the shoots as infested or not infested rather than count the total larvae.

The survey consists of checking 30 shoots and staminate flowers that can be reached from the ground. These are taken from at least five trees at each location and an attempt is made to take approximately 15 flowers and 15 shoots. Some years, however, this is not practical as flowers are scarce, so a majority of shoots are used. A count of 20 or more infested shoots and flowers is considered sufficient population to cause moderate to heavy defoliation.

Jack Pine Budworm Pre-Spray Counts

This survey is conducted when populations are high and a suppression program is planned.

These counts are usually made in mid-June when the larvae are in the fourth and fifth instar, just prior to the time when chemical suppression would be done. Stands have already been evaluated and designated for control should populations persist. At predesignated locations ten 15 inch twigs (15" of needle bearing surface) are clipped from at least five different trees. These are taken at mid-crown with pole pruners. A basket should be attached to the pruner as the larvae spin down readily when a branch is disturbed. The larvae on each branch are counted and recorded. The counts are then totaled for each plot and an average number of larvae per 15 inch twig is determined for the plot. An average of three larvae per 15 inches of needle bearing surface is considered sufficient to cause serious defoliation. Stands with average counts of three or more larvae will be included in the control operation.

Jack Pine Budworm Late Larval Counts

This survey is conducted each year throughout the jack pine type. It is conducted in late June when a majority of the larvae are in the fifth and sixth instar. Two 15 inch branches (15 inches of needle bearing surface) from each of three trees are clipped at each plot. These are taken at mid-crown with a pole pruner with basket attached. The larvae on each twig are counted and the total for each tree is recorded. This is not used to determine or evaluate populations, but rather to provide an indication of larval parasitism since a majority of the parasitized larvae have perished before reaching the later instars. Here again, three late instar larvae per 15 inch branch are considered a high population.

Jack Pine Budworm Pupal Survey

This survey is conducted every year throughout the jack pine type. It is made in July when a majority of the insects are in the pupal stage. Some adults may already have emerged, but the empty pupal cases are collected and counted as emerged. At each stop the pupae are collected on a time basis. Starting time is recorded and if five pupae are not found in five minutes, the collection is terminated. If five pupae are found in five minutes or less, the collection is continued until 25 pupae are found. The time is recorded for collecting the 25 pupae. The pupae are placed in individual gelatin capsules as they are found and these are taped together and labeled for each plot. They are then returned to the laboratory where they are held until emergence takes place. Later, the adults, parasites, and non-emergence is recorded. This gives a good indication of the numbers and kinds of pupal parasites active in the population. The number of adults which emerge is also a good indicator of populations for the following year.

Jack Pine Budworm Overwintering Larval Survey

This survey was conducted throughout the jack pine type for several years. Results were variable and it was discontinued after the collections showed little or no budworm population present, yet larval counts in the spring were extremely high. This very likely was due to variations in the insects selection of overwintering sites, possibly due to weather conditions. The undependable results made it of little use as a population indicator.

The survey consisted of collecting two 15 inch branches (15 inches of needle bearing surface) from each of three trees, plus a 15 inch bare twig at least one-half inch in diameter from each tree. They were taken from mid-crown with pole pruners. These were cut in small pieces and placed in quart size plastic bags — two for needle bearing material and one for bare twigs. The collections were then sent to the Madison laboratory where they were placed in cans. A small vial was attached to the top of the can and they were exposed to light for 24 hours a day. The larvae attracted by the light into the vial were removed, counted, and recorded each day. After a reasonable period of time the can was opened and larvae inside were counted and recorded.

Jack Pine Management

by
S. D. Weber

Wisconsin boasts about 200 thousand hectares of jack pine forest. While almost all of this acreage has suffered some feeding by jack pine budworm, the approximately 100 thousand hectares of jack pine that lie in the northwest corner of Wisconsin have received special attention from this insect. Over the past twenty-five years, jack pine in this region has weathered three major outbreaks (the last outbreak covered 52,600 hectares) and witnessed high endemic budworm populations in the years between outbreaks. The soils of this region are dominated by coarse sands which are low in nutrients, organic matter, and moisture holding capacity. The bulk of Wisconsin's budworm control efforts past and present have occurred in the northwest.

Past Practices

During the 50's and 60's, budworm infestations were combatted with aerial applications of chemical insecticides. The insecticides were applied both for population suppression and foliage protection. This chemical control was successful as budworms were killed and trees remained largely green. While no one doubts that insecticides can kill budworms, the actual benefits to the forest are often difficult to quantify. Once an area is sprayed, one can never really know how that particular budworm population would have responded in the absence of treatment. We don't really know how much feeding damage would have occurred, nor can we tell how the trees would respond to different levels of defoliation since we can't accurately predict the weather for the growing season. Also, in light of fluctuating timber markets, jack pine salvaged now may carry a higher price than the timber would have brought in ten years.

Present Situation

In Wisconsin, widespread chemical control of jack pine budworm outbreaks does not remain a viable option. Jack pine is a crop of very low unit value which cannot bear large production costs and remain economically attractive. The direct costs of spraying programs are much greater now than in the past. We are also more aware of the indirect, environmental costs of chemical treatment which include human health risks, chance for offsite application and water contamination, and the suppression of beneficial insects and spiders which act as natural enemies of budworms. This suppression of natural enemies can actually prolong outbreaks by interfering with the natural forces which cause budworm populations to collapse. Finally, as the human population of this region has increased, the social and political opposition to insecticide spray projects has mounted dramatically. These factors, coupled with the aforementioned difficulty in demonstrating concrete benefits from spraying, have made widespread insecticide treatment of jack pine budworm infestations an interesting footnote in Wisconsin history.

Basic Philosophy

Jack pine budworm has a long evolutionary history with its host, jack pine. As with any well evolved parasite, jack pine budworm benefits from the survival of its host and has developed mechanisms to encourage this. Examples include females vacating heavily defoliated stands to oviposit and second instar larvae dispersing out of severely attacked areas. In Wisconsin, budworm populations almost always collapse before the attacked jack pine stand is decimated. Our current management of this timber type involves enhancing the budworm's natural tendency to allow its host to survive. We employ silvicultural manipulation of stands to develop jack pine forests which are less susceptible to being attacked by budworm and less vulnerable to suffer significant mortality and topkill in the event of budworm attack. The specifics of our management involves a two-pronged approach. The first prong is maintaining jack pine stands at maximum vigor so that the trees are less vulnerable to damage and death following budworm feeding. The second prong involves minimizing staminate flower production in jack pine stands which reduces the survival of second and third instar budworm larvae in the spring. The lack of male flowers forces small larvae to feed out on the developing shoots which are a less nutritious food source than pollen cones. The lack of nutrition elongates the budworm feeding period. The delicate young larvae are also forced to feed out on exposed locations where they are fair game for unfavorable weather conditions and easy prey for predators and parasites. These two factors combine to reduce budworm survival at this critical life stage.

As a result, the jack pine forest will support smaller populations of budworm which are less likely to cause serious damage. We know this plan is far from perfect and that our jack pine stands will suffer some defoliation and growth loss, but we feel that we can prevent or, at least, minimize mortality and topkill. Essentially, we are attempting to develop a peaceful coexistence, a detente if you will, with the jack pine budworm.

Specific Practices

Stand Density

It is essential to maintain proper stocking in a jack pine stand in order to maintain individual tree vigor and reduce staminate flowering. We recommend a stocking level of 16 to 25 square meters of basal area per hectare from age 25 until harvest. Overstocked stands have low tree vigor and contain many intermediate or suppressed trees which can be heavy male bloomers. In stands above 28 basal area, a pulpwood thinning should increase the vigor of the trees while reducing male flowering. This thinning will also concentrate growth on better stems while capturing some revenue from the stand. Stands within the prescribed basal area range can also be thinned to obtain revenue and improve growth of the better trees without increasing the risk of budworm attack. Stands below 14 square meters of basal area which have been open grown throughout their lives should be harvested. These understocked orchards of wolf trees are making no value growth while they harbor enormous numbers of budworms. These stands serve as budworm reservoirs for large scale outbreaks and should be eliminated.

Stand Age and Age Diversity

Overmature jack pine stands have trees that are low in vigor and intolerant of budworm defoliation. Old stands which are damaged by budworm are much more likely than younger stands to succumb to secondary pests such as pine engravers, **Ips pini**, and armillaria root rot. On better sites, where jack pines remain vigorous longer and where saw bolt production is possible, we recommend that rotation age be set at site index minus five years. For example, a site index 60 stand would be cut at age 55. On poorer sites (SI 55 or less) jack pine should be harvested for pulp at age 40. On these poorer sites, our jack pine stands begin to deterioriate and break up beyond 45 years of age with significant mortality factors including armillaria root rot, bark beetles and stem breakage by ice and wind.

Whenever possible, age class diversity in large jack pine areas should be promoted. Large contiguous blocks of mature and overmature jack pine should be avoided because these stands are susceptible and vulnerable to budworm outbreaks and can also hold high budworm populations that will attack other, younger stands in the area. For example, a section (260 hectares) of even age jack pine could be harvested in three cuts; one five years before specified rotation age, one at rotation age, and one five years beyond rotation age.

Stand Size and Shape

When growing jack pine, especially in budworm prone areas, attention should be paid to stand size and shape. Jack pine stands more than a square mile (260 hectares) should be avoided. If possible, even smaller stands (65 hectares or less) should be encouraged as this will prevent large areas from becoming attractive budworm habitat at the same time. When cutting jack pine, care should be taken to minimize the amount of edge created. Budworms tend to concentrate along stand edges, and jack pine trees released along the edge of cuts often respond with profuse crops of male flowers. Preferred stand shapes include circles, squares, broad ovals, and thick rectangles. Thin strip cuts, irregular boundaries, and aesthetic leave strips or islands should be avoided, especially during salvage cutting in budworm damaged stands. These leave strips will serve as budworm reservoirs and defeat one of the main purposes of the cut which was to eliminate a population of budworms. One last point, clearcuts in jack pine should always be clean; lonely hearts and unmerchantable whips left standing are right out!

Species Diversity

Finally, in areas prone to chronic budworm infestations conversion to non-host species should be considered. The primary alternative to jack pine on these sandy soils is red pine in our area. While jack pine budworm will infest red pine, they rarely cause significant damage to this species. In general, when artificial regeneration is called for red pine will be favored over jack pine. On better sites white pine and high quality aspen can be grown instead of jack pine. Also, given the recent popularity of wood heat, scrub oak is becoming a viable and valuable alternative to jack pine on the southern end of our jack pine region. For a rule of thumb, we try to keep about 50% of the forested areas in this jack pine region in alternate species.

Conclusion

In the preceding discussion I have outlined our major control tactics for jack pine budworm as well as the overall strategies behind them. While our program is primarily silvicultural control, it can be considered integrated pest management in that we use silvicultural control to augment the efforts of natural predators and parasites of the jack pine budworm.

Our management strategy for jack pine budworm has met with ready approval from the foresters in the region as they had considerable input into the formulation of the plan. This cooperation enabled us to integrate our knowledge of the insect and our foresters' experience with the tree in order to formulate a management strategy based on good, sound silviculture. I feel this enthusiastic support and cooperation of our foresters is the key to success as they are the dedicated professionals who will put the theory into practice on the ground.

The Jack Pine Budworm, History of Outbreaks, Damage, and FIDS Sampling and Prediction Systems in the Prairie Provinces

by
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*The jack pine budworm, **Choristoneura pinus pinus** Freeman is the most important insect pest of jack pine in Manitoba and Saskatchewan. But it also attacks other pines, including Scots and lodgepole pines. Forest Insect and Disease Survey (FIDS) records budworm outbreaks since 1936 in the two provinces (Anon. 1936-1985; Brandt and McDowell 1968; Deboo and Hildahl 1968). The term outbreak refers to the occurrence of successive years of high budworm populations characterized by marked increases in expansion and intensity of attack, and by moderate to severe defoliation (31-100 per cent defoliation of current foliage). Most outbreaks have lasted two to five years with near complete defoliation for two to three consecutive years, and may have resulted in extensive top kill, reduced radial increment, and in tree mortality.*

This report summarizes the recorded outbreaks and resulting damage to jack pine forests, and jack, lodgepole, and Scots pines plantations in Manitoba and Saskatchewan and the FIDS sampling methods and techniques used in detecting, monitoring, and forecasting budworm outbreaks.

History of Outbreaks

Since 1936, reference to major outbreaks of the jack pine budworm in Manitoba and Saskatchewan fall into five distinct periods listed below and indicated in the composite maps showing areas of moderate-to-severe defoliation (Figures 1-5).

Composite Major Outbreak Period for Manitoba and Saskatchewan
1936 - 1950
1953 - 1957
1959 - 1967
1974 - 1979
1982 -

Specific outbreak periods when moderate to severe defoliation occurred in Manitoba and Saskatchewan are shown below:

Manitoba	Saskatchewan
1936 - 1950	1939 - 1941
	1944 - 1945
1953 - 1957	1954 - 1957
1959 - 1967	1963 - 1967
1974 - 1979	1975 - 1978
1982 -	1984 -

Outbreaks in Manitoba seem to have been of longer duration and resulted in more damage than in Saskatchewan. Records indicate the outbreaks were of variable duration and occurred over short intervals. Most lasted two to five years and some caused moderate to severe defoliation over many hundreds of hectares of jack pine stands. during most of the intervening years of these outbreak periods, budworm populations were either in an early expansion phase, declining, at endemic levels or not detected. However, localized areas of light to moderate defoliation were also characteristic of most intervening years. A detailed cartographic history of the jack pine budworm in Manitoba and Saskatchewan from 1938 to 1967 was given by Brandt and McDowall (1968). There were no reports of this budworm in Alberta until 1985 when moderate defoliation was recorded by FIDS in small isolated stands of jack pine in central Alberta.

Manitoba

In Manitoba, budworm outbreaks have generally coincided with the outbreaks reported in northwestern Ontario. Periodic outbreaks, ranging from one to four years duration in localized areas occurred continuously in the southeastern part of the province from 1936 to 1950 (Figure 1). A second outbreak period occurred between 1954 and 1957 when jack pine stands were moderately to severely defoliated over extensive areas of the Sandilands and Belair provincial forests. During this period, particularly severe defoliation occurred on jack pine, lodgepole pine and Scots pine plantations in the Spruce Woods Provincial Forest. The 1963-1967 outbreak was the most widespread to date

and occurred in the above mentioned provincial forests and in additional natural stands. In 1967, this outbreak declined in many areas and severe defoliation was confined to jack pine stands east of Lake Winnipeg and in the Whiteshell Provincial Park. This decline continued in 1968 and 1969 when light to moderate defoliation occurred in the Sandilands Provincial Forest. A series of small outbreaks or increases in population were recorded in southern Manitoba from 1970 to 1973. The 1974-1979 outbreak caused moderate to severe defoliation in plantations and natural stands in the Belair, Sandilands, and Spruce Woods provincial forests. This outbreak peaked in 1979 when moderate to severe defoliation occurred within an area of about 500 000 ha. The outbreak collapsed in 1980. Adverse weather conditions, poor bud growth, and inhibited male flower production contributed to the decline.

The current budworm outbreak, first recorded near Grand Rapids in central Manitoba in 1982, is the most extensive and the most northern of recorded outbreaks. Moderate to severe defoliation occurred on jack pine within an area of 46 000 ha in 1982 and increased over three-fold in area annually in 1983 and 1984. In 1985, the area within which defoliation occurred reached an all time record high of 2 040 000 ha.

Saskatchewan

In Saskatchewan, the history of jack pine budworm outbreaks has been very similar to that in Manitoba, although damage in Saskatchewan has not been as widespread or severe. The first recorded outbreak was observed in Fort à la Corne Provincial Forest in central Saskatchewan in 1939. After several years of moderate to severe defoliation with a decline in 1942 and 1943, the outbreak terminated in 1945. During the 1954-57 outbreak period this budworm was common in the Nisbet and Fort à la Corne provincial forests but populations did not intensify and damage was light. The outbreak in 1963-1966 caused severe defoliation over extensive areas, mainly in the Nisbet, Pines, Canwood, and Fort à la Corne provincial forests, but by 1967 the budworm had collapsed in most areas. The recent major outbreaks in 1976 to 1979 in the Nisbet and Torch River provincial forests caused moderate-to-severe defoliation over 20 000 ha of jack pine forests. This outbreak collapsed in 1979.

The current jack pine budworm outbreak was observed in 1984 along the eastern border of the province within an area of 27 000 ha. In 1985 the area of moderate-to-severe defoliation covered an estimated 130 000 ha and occurred in eastern Saskatchewan to the Manitoba border within the Nipawin - Tobin Lake area and the Torch River, Fort à la Corne, and Nisbet provincial forests.

Jack Pine Budworm Damage

Defoliation by the jack pine budworm spreads from the top of the tree crown downwards. Consequently, top kill and reduced annual growth are the most common losses. However, tree mortality can occur after two or more years of severe defoliation especially in jack pine stands on poor sites. Extensive top-kill, reduced radial growth, and tree mortality have been reported in Canada by Brandt and McDowell (1968), Cerezke (1978), DeBoo and Hildahl (1968), and Howse (1984).

In Manitoba, considerable data on budworm damage has been accumulated from earlier infestations which indicate that jack pine budworm is a serious pest. In 1944, jack pine stands in the Sandilands Provincial Forest suffered a 12-60 per cent incidence of top-kill (1-2.45 m in length); and in a 1947 survey of this forest, top kill averaged 6 per cent. In 1949, a cruise in jack pine stands near Gypsumville indicated 10 per cent mortality, mostly in the smallest trees less than eight cm dbh. A similar cruise conducted in 1956 in the Sandilands indicated a maximum loss of 11 per cent (6 per cent average) in basal area of the stand due to tree mortality.

Reeks (1958) noted that Scots and lodgepole pine were more seriously damaged by the jack pine budworm than jack pine. Severe infestations of 1956 and 1957 in jack, lodgepole and Scots pine plantations planted in Spruce Woods Provincial Forest during 1904 to 1929, resulted in complete loss of current foliage for two consecutive years and killed about 22 per cent of 30-year-old Scots pine, and caused serious top-kill on most of the remaining trees. Scots pine severely defoliated also had radial increment losses of 50 per cent in the first year and 80 per cent in the second year.

During a seven year (1973-1979) infestation in pine plantations in the Spruce Woods Provincial Forest, 40 per cent - 75 per cent tree mortality occurred in areas left untreated by insecticides, for two years of successive severe defoliation. The extent to which mortality would have occurred is unknown as insecticide application was carried out in 1975 (Keith Knowles, personal communication 1986). In the current outbreak, overmature stands in the Talbot-Moose Lake area has 35 per cent incidence of top-kill and tree decline following two years (1983 and 1984) of severe defoliation (Anon 1985).

In Saskatchewan, no reports of top-kill and tree mortality were found for the 1964-67 outbreak or for any of the previous outbreaks. However, the major outbreak of 1976 to 1979 in the Nisbet and Torch River provincial forests caused a 20-30 per cent incidence of top-kill in 1978 in some areas of the Nisbet. But tree mortality that could be attributed to budworm

defoliation was considered insignificant (Hiratsuka *et al.* 1981). Radial growth losses were particularly evident in the 1977 and 1978 increments, and tree growth suppression continued into 1979 and 1980 increments, even though budworm populations collapsed in 1979.

FIDS Sampling and Predictive Systems Jack Pine Budworm

FIDS sampling procedures for the jack pine budworm, have been aimed primarily at detection and forecasting of infestations.

Detection has been made through defoliation surveys from aircraft with ground checks at accessible points. Therefore, aerial surveys have provided a cartographic record of defoliation ranging from light, moderate to severe intensity classes. The following guide has been used for estimating defoliation of current needle growth:

a) Estimation of infestation intensity:
Light: Tree only slightly red at tip of crown.
Moderate: Redness clearly evident from the air, some green foliage showing.
Severe: Foliage red over entire crown, little or no green foliage showing.

b) Larval feeding damage classes:
Light: Up to 30 per cent of current foliage loss.
Moderate: 31-60 per cent of current foliage loss.
Severe: 61-100 per cent of current foliage loss.

Forecasting by the egg mass sampling method. At each sampling point or location, two 45 cm branch tips were removed from the mid-crown of each of five pine trees. The branch width was measured at one half length of the branch sample and multiplied by 45 cm to give an estimate of surface area of foliage. Egg-masses per branch tip were counted in the laboratory and egg-masses per 10 m^2 of foliated branch sample calculated. Prediction of the coming year's population level was made by a modification of Morris's method (1955) as developed for the spruce budworm:

Classification of Infestations

Light: 25 or less egg masses/10 m^2 of foliage area.
Moderate: 26-150 egg masses/10 m^2 of foliage area.
Severe: 151 or more egg masses/10 m^2 of foliage area.

This is on the assumption that statistics derived for the spruce budworm can be applied to the jack pine budworm as well. This assumption needs checking.

Losses due to dispersion of larvae on silken threads occur immediately after egg hatch and again the following spring, accounting for up to 90 per cent or more mortality of these larval stages. This may explain to some extent why egg mass surveys made for prediction of budworm abundance often give low predictive values. Also the regularity in the duration of outbreaks (two to four years) in pine stands; and the role of weather, production of male flowers, and other factors in ending outbreaks must be considered in the use of egg-mass numbers for predicting infestations a year in advance.

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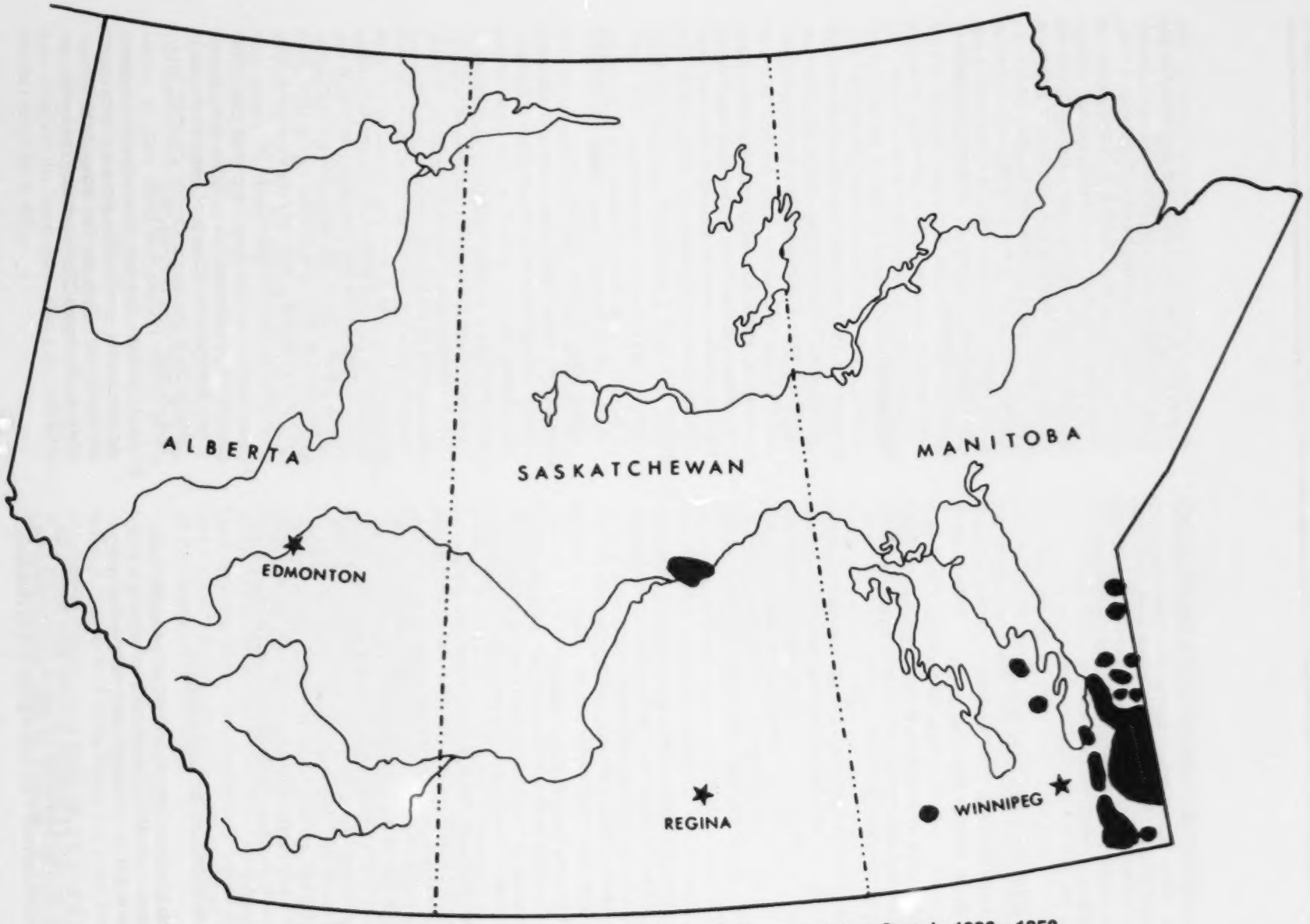

Fig. 1 Main outbreak areas of the jack pine budworm in western Canada 1936 - 1950

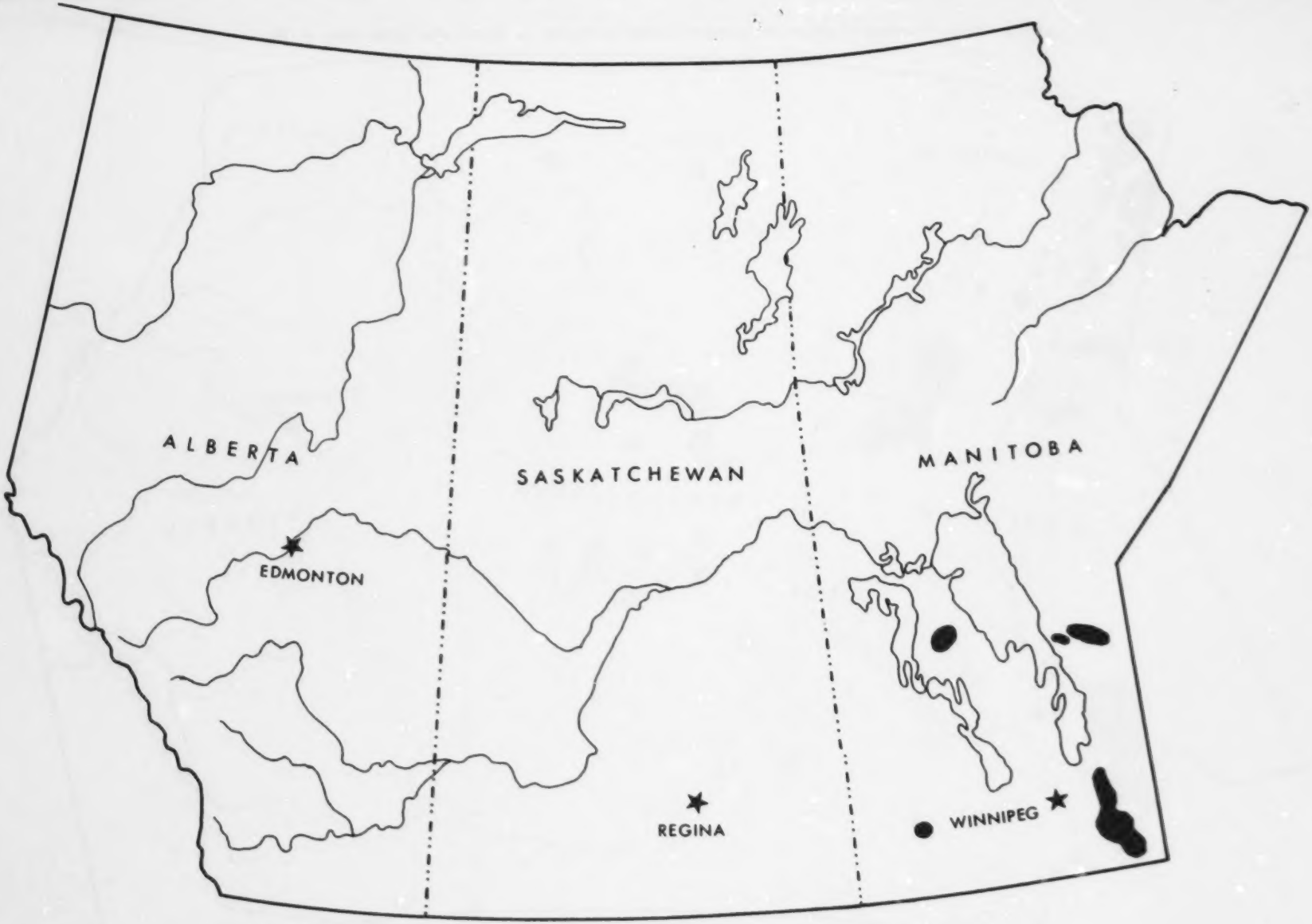

Fig. 2 Main outbreak areas of the jack pine budworm in western Canada 1953 - 1957

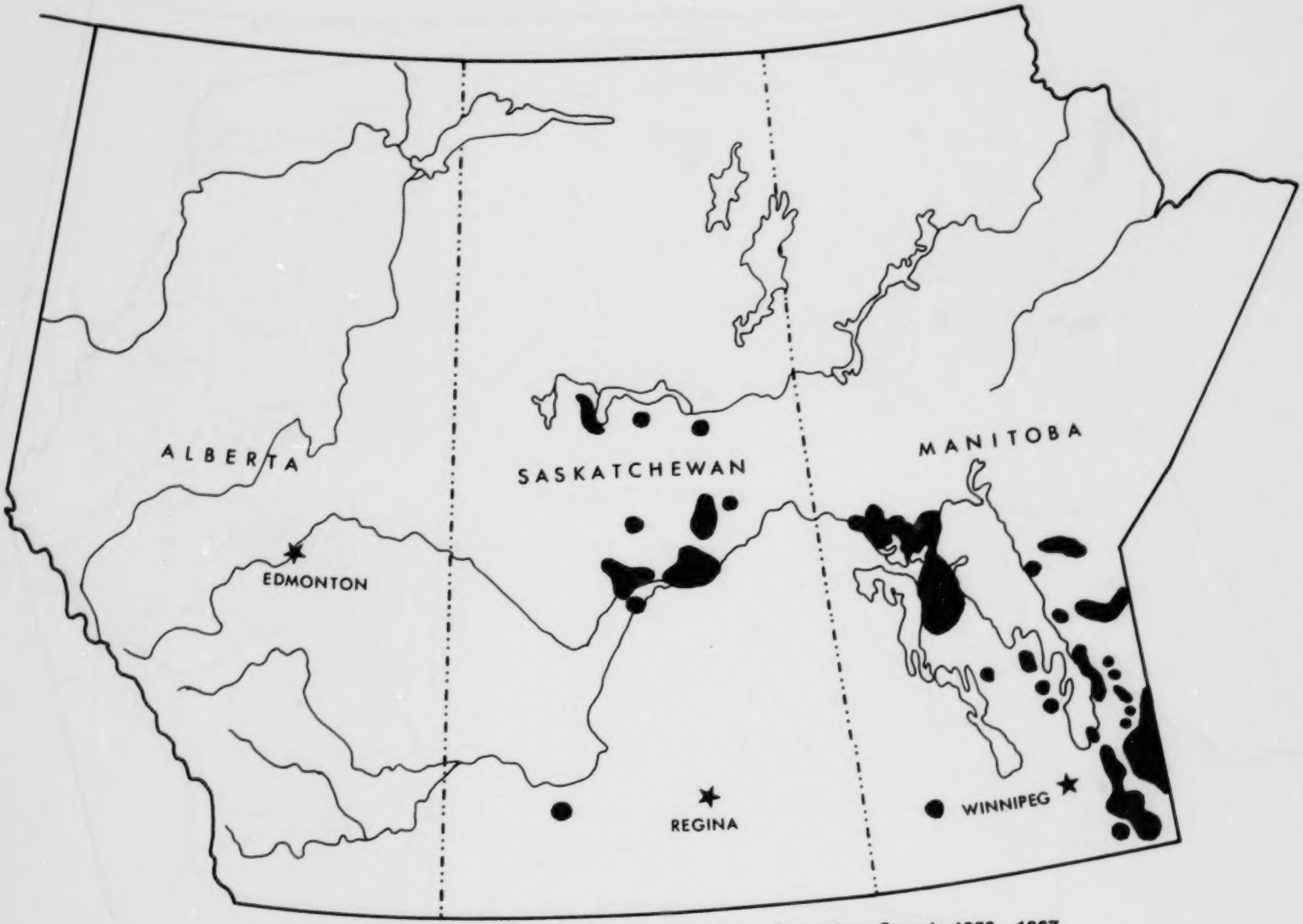

Fig. 3 Main outbreak areas of the jack pine budworm in western Canada 1959 - 1967

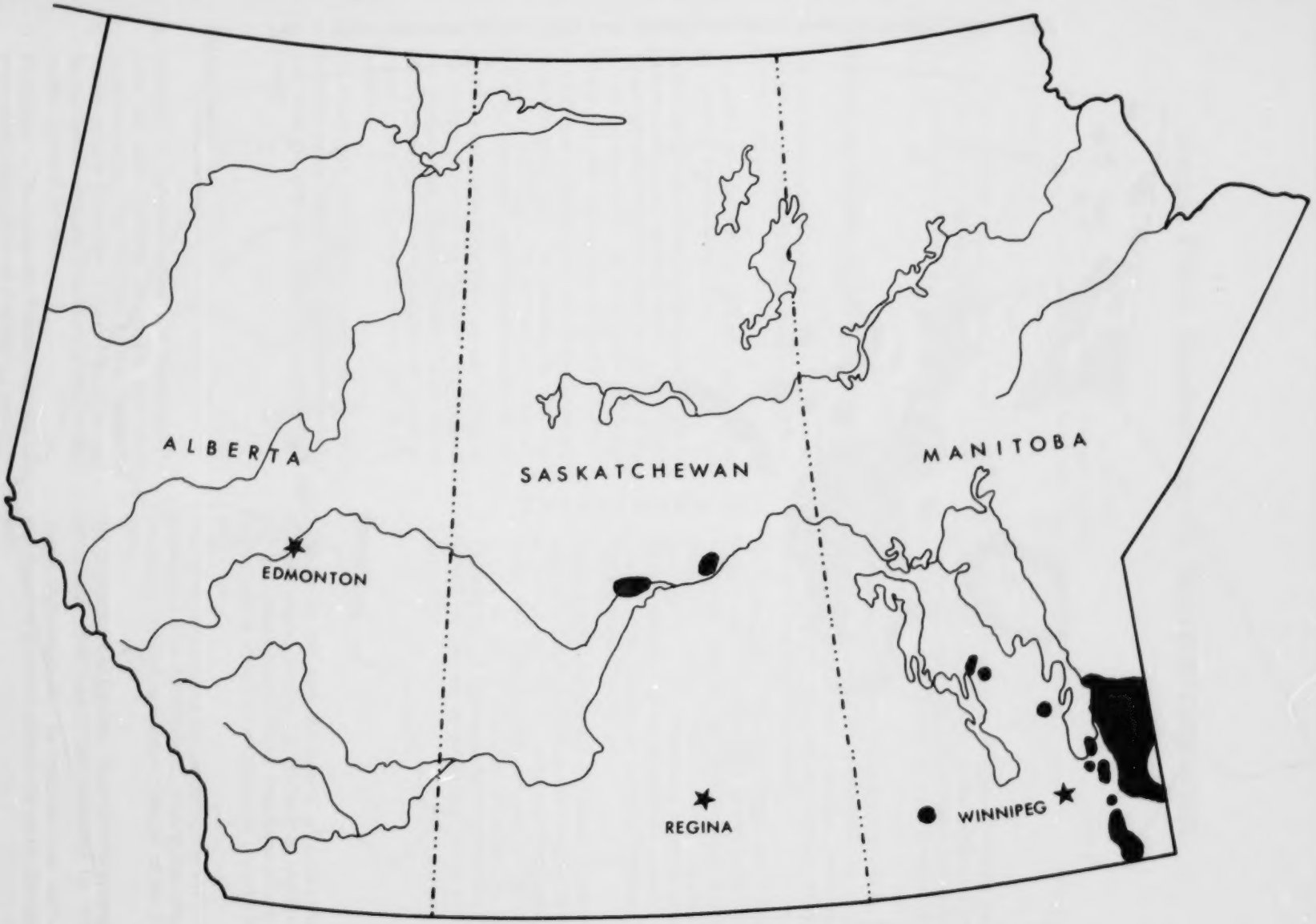

Fig. 4 Main outbreak areas of the jack pine budworm in western Canada 1974 - 1979

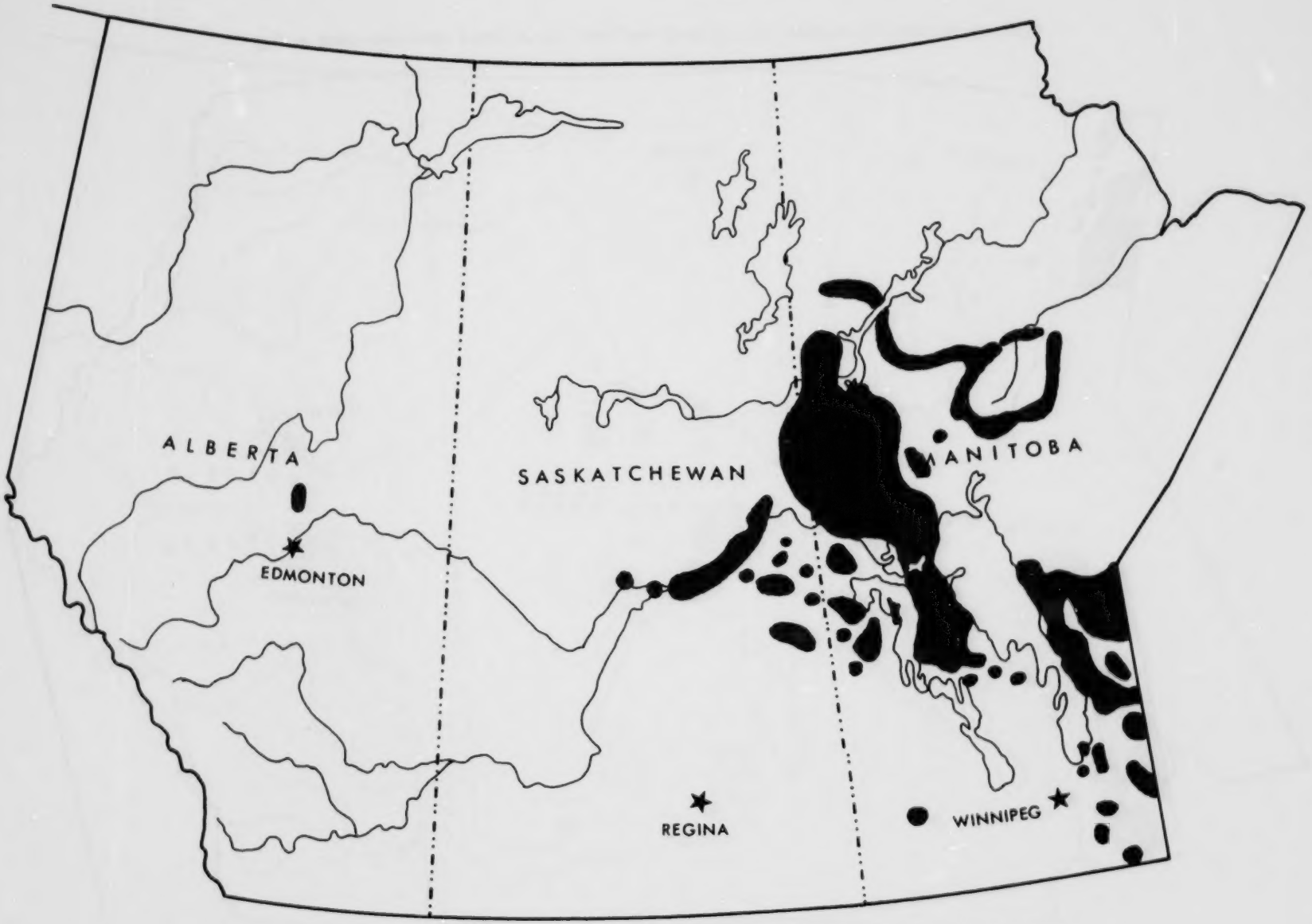

Fig. 5 Main outbreak areas of the jack pine budworm in western Canada 1982 - 1985

Jack Pine Budworm in Saskatchewan

by
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Jack Pine Budworm ***(Christoneura pinus pinus Freeman)*** *has long been a relatively serious insect problem of Jack Pine Plantations and natural stands in Saskatchewan.*

History of Outbreaks

1. The first recorded outbreak was reported in 1939 in the Fort à la Corne Provincial Forest, 50 km west of Prince Albert.

   The outbreak terminated in 1945 after six years of moderate to severe infestation.

2. Moderate to severe infestations occurred again in Eastern and Central Saskatchewan in 1963 causing severe defoliation and injury especially in the Nisbet Canwood and Fort à la Corne provincial forests. By 1967 the population had collapsed.

3. A moderate infestation of Jack Pine Budworm occurred again in 1977, but collapsed in 1980. The infestation was fortunately confined to the Nisbet, Fort à la Corne and Torch River provincial forests.

4. In 1984, infestations occurred in several locales in the Eastern portion of the Province near Nipawin and Hudson Bay, Saskatchewan. Moderate to severe defoliation was estimated by the Canadian Forestry Service to have occurred over 26,800 hectares.

   The infestation expanded so rapidly that by 1985 the entire eastern portion of Saskatchewan's commercial forest zone was moderately to severely infested.

Surveys

a. **Detection** — Detection of the most recent infestations has been primarily by ground and aerial reconnaissance. The Northern Forest Research Centre of the Canadian Forestry Service and Saskatchewan Forestry Division have co-operated in both types of surveys.

b. **Prediction** — The Canadian Forestry Service has been solely responsible for predicting population trends and severity of infestations. Forest Insect and Disease survey staff at the Northern Forest Research Centre deploy pheromone bait stations and conduct egg counts in order to make these predictions.

c. **Monitoring** — Forests Insect and Disease Survey staff monitor Jack Pine Budworm using ground and aerial reconnaissance surveys. Moderate to severe infestations are broadly mapped at a resolution of one square kilometre.

   The Saskatchewan Forestry Division also monitors these infestations using ground and aerial reconnaissance methods. However, should these infestations persist, **stand** level mapping of moderate to severe infestations could be accomplished with the same techniques used in the monitoring of spruce budworm (**Choristoneura Fumiferanan Clem.**).

   Several localized Spruce Budworm infestations have been photographed in a twin engine aircraft, at a scale of 1:12,500, using modified colour infrared film. 1985 photography was completed at a cost of $16.37 CDN/line kilometre or $8.00 CDN/sq. km. of coverage. Aerial photos are interpreted for degree of infestation using a Zeiss stereopret.

Control

Because of the periodic nature of outbreaks in Saskatchewan, damage has not been as widespread as it is in Manitoba or Ontario. Populations have collapsed before chemical or biological controls were ever used.

Biological control using DIPEL during the 1977-1980 infestations was considered. Spraying became unnecessary due to the sudden collapse of the population.

Six formulations of Bacillus Thuringiensis were given temporary registration in Saskatchewan for 1985.

Three derivatives of fenitrothion are currently registered as chemical controls for use in Saskatchewan.

Research

Current research in Saskatchewan is targetted at determining an accurate cost-effective technique for mapping and determining the degree of infestation of the spruce budworm.

In co-operation with Saskatchewan Research Council and the Canadian Centre for Remote Sensing, comparisons of LANDSAT Data, Meis imagery, color I.R. aerial photography and reconnaissance will be made.

There is little doubt that the remote sensing techniques used for monitoring spruce budworm can also be effectively used for monitoring jack pine budworm.

Forestry Division is also currently exploring the possibility of co-operating with the University of Saskatchewan, Faculty of Applied Microbiology in testing the larvicidal efficacy of various strains of Bacillus Thuringiensis. Funding for biological control research by universities is available through programs sponsored by the Canadian Forestry Service, the Saskatchewan Department of Agriculture, and the Federal Department of Regional and Industrial Expansion.

In summary, because only minor damage has been caused by periodic infestations little or no control measures have ever been undertaken. Subsequently, Saskatchewan has only just begun very basic research into survey methods.

However, the recent explosive expansion of populations has convinced us that our research efforts must be expanded. We cannot afford the luxury of always depending on environmental and biological factors to control budworm populations for us.

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Impact Studies of the Jack Pine Budworm, *Choristoneura pinus pinus*, in Nisbet Provincial Forest, Saskatchewan

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*An outbreak of the jack pine budworm, **Choristoneura pinus pinus** Freeman, occured in the Nisbet Provincial Forest in central Saskatchewan during 1975 to 1979 and caused moderate to severe defoliation for two consecutive years of 50-55 year old naturally-grown jack pine (**Pinus banksiana** Lamb.) stands. Studies of the impact of defoliation damage on radial stem growth, leader and shoot kill, cone damage, and stem volume loss were undertaken to assess these effects during the four outbreak years, 1975-1978. The results are based upon stem analyses of defoliated jack pine from seven sites distributed within the outbreak area.*

Radial growth was significantly reduced throughout the stem in the 1977 and 1978 increments, and additional losses probably continued for at least two post-outbreak years. Height growth reduction and top kill were variable, but occurred during 1976, 1977, and 1978. In six sites that sustained the most severe levels of defoliation, no staminate flowers or female cones were observed in 1978, and some trees had no first or second-year cone development in 1977. Volume growth, estimated for each of the four outbreak year increments (1975-1978), was compared with the mean annual stem increment volume of the five previous non-outbreak years (1970-1974), and indicated reductions of up to 47 per cent and 91 per cent respectively for the 1977 and 1978 increments.

The jack pine budworm, **Choristoneura pinus pinus** Freeman, has long been known as a serious defoliator of jack pine (**Pinus banksiana** Lambert) stands and plantations in Canada and the Lake States of the U.S.A. (Anon. 1936-1979; Coulson and Witter 1984; DeBoo and Hildahl 1968; Graham 1935; Prebble 1975). In Canada, outbreaks of this insect have recurred at short intervals over the past 45 years, particularly in western Ontario, Manitoba, and Saskatchewan (Anon. 1936-1979; DeBoo and Hildahl 1968). Typically, most outbreaks have lasted two to five years with near complete defoliation sustained for two to three consecutive years. This has often resulted in extensive top kill, reduced radial increment, and in tree mortality in some cases (Brandt and McDowell 1968; DeBoo and Hildahl 1968; Howse 1984).

In 1975, low populations of the jack pine budworm were observed for the first time since 1969 in the Nisbet Provincial Forest near Prince Albert, Saskatchewan, and caused light defoliation at scattered locations. Major expansion and intensification of defoliated areas developed in 1976 and 1977, when an estimated 18,700 ha were rated as moderately to severely defoliated. The total area classed severe declined to 8700 ha in 1978, and the population subsequently collapsed in 1979 and 1980 (Anon. 1977; 1978-79; Hiratsuka et al. 1980; 1981). During the main outbreak period from 1975 to 1978, the infestation progressed without human intervention, thus providing an opportunity to document the major impacts the budworm had on the pine component during these four years.

This report summarizes a study undertaken in 1978 to evaluate the cumulative feeding effects of the jack pine budworm larvae up to the end of the 1978 growing season. Defoliation effects on radial growth increment pattern, leader and twig mortality, cone damage, and stem volume were documented.

Methods and Materials

Six plot sites with similar levels of defoliation damage were selected within the main outbreak area west of Prince Albert, Saskatchewan (Fig. 1; plots 1-6). Two codominant jack pine trees were cut at the end of August, 1978, in each plot and measured for total height, diameter at b.h., total age, and length of live crown. Eight discs were cut from the main stem, starting at one m below the tree terminal and at one-m intervals to the base of the crown, and one disc at b.h. level. These served to obtain radial growth profile patterns vertically and horizontally within the stem. Each disc was sanded smooth and marked with three radii spaced 120° apart; all annual increments were

measured to 0.01 mm. An average width for each years growth was calculated for each disc back to the pith, or to a maximum of 20 years (1958).

Observations were made on the presence or absence of male and female flowers, external feeding damage to female cones, the condition of the 1978-formed buds, leader and twig kill in the upper crown, and an estimation of defoliation separately for each of the years 1976, 1977, and 1978. Percentage defoliation for the three years was estimated from 10 shoots clipped from the upper crown of each tree. On each shoot defoliation was estimated in 10 per cent increments, and a composite average was obtained from all shoots of each tree for each year.

A seventh plot was established near the margin of the main infestation (Fig. 1; plot 7) where less severe budworm feeding damage had occurred during 1976 to 1978. Four codominant jack pine trees were cut and discs were taken similarly as described for the other six plots. Data from these trees served for comparison with those from plots one to six. Growth profiles of the sampled jack pine stems were plotted graphically to illustrate radial and vertical growth reductions within the stem.

Radial growth was also measured on three increment cores taken at b.h. level on each of four non-host tree species, two white spruce (**Picea glauca** Moench Voss) and two eastern larch (**Larix laricina** (DuRoi) K. Koch) sampled near plot one, and similarly replicated near plot four (Fig. 1). All growth profiles for each tree species and site were combined to provide an average radial growth curve for the period 1959 to 1978. This was to provide a comparison in growth pattern of adjacent non-host trees with that of the budworm defoliated jack pine, and to indicate the potential growth trend in the absence of defoliation.

In addition, annual precipitation records from the nearest weather station at Prince Albert were used to calculate seasonal precipitation during the period April 1 to August 31, annually from 1958 to 1978. This was to establish whether moisture conditions for the general area were adequate or likely a limiting factor in tree growth.

Volume Loss Estimation

Estimates of yearly volume increment from 1970 to 1978 were calculated separately for the 12 trees from plots one to six and for the four trees from plot seven. the volumes were computed on the basis of total tree height by considering the shape of the stem as conoid and applying the formula:

$$V = 1/3\ \pi\ r^2\ h,$$

where: V is volume in cm^3; r is radius in cm at dbh; h is total height of the tree stem (cm) and π is a constant 3.1416.

Separate volume estimates were derived for each of the known budworm defoliation years 1975, 1976, 1977, and 1978. These were compared to the mean annual volume estimated for the previous five-year non-outbreak years, 1970-1974.

Average radial measurements at the bh level of the stem were made from pith to the outside of each increment formed in 1969, 1974, 1975, 1976, 1977, and 1978, to provide the cone base measurements. However, for the purpose of estimating the volume of each conoidal-shaped increment, the actual ring width for each growth year was calculated as the mean width from all eight stem levels. This provided the best estimate of volume by taking into account the highly variable ring width vertically up the stem that reflects both intrinsic growth pattern and defoliation effects.

Annual internodal lengths of stem produced from 1973 to 1978 were measured on all tops of sampled trees so that total cone height could be adjusted for the volume calculation of each annual increment. Mean annual height growth during the two pre-outbreak years, 1973 and 1974, was used to approximate annual height growth during the five-year pre-outbreak period, 1970-1974.

Results and Discussion

The characteristics of the sampled jack pine trees are summarized in Table 1. All trees selected at each site were representative of the codominant crown stratum, and indicate a size range suitable for pulp, pole, and post utilization.

Foliage, Shoot, and Flower Defects

Percentage defoliation, based upon upper crown estimates, indicated that almost all needles produced (96 per cent) in 1976 and 1977 were destroyed in plots one to six, whereas in 1978 the actual needle loss was reduced to 23 per cent (Table 2). This suggests that some defoliation may have occurred on at least some of the sample trees in 1975, believed to be the first year of visually detected defoliation (Anon. 1976). However, the main damage impact effects reported here are no doubt a result of the defoliation years 1976-77. Although larvae prefer current year needles as food, they may also feed on the previous year's needles in some cases (Batzer and Jennings 1980; Kulman et al 1963). Hence some back-feeding may have occurred in both 1976 and 1977, but this could not be differentiated in the present study.

Defoliation at plot seven was not as severe during 1976 and 1977 as in plots one to six, but showed the same trend of decline in 1978. In plots one to six severe defoliation on most sampled trees had

extended throughout the tree crown, but in plot seven defoliation was confined mostly to the upper third of the crown. Consequently, little new shoot growth occurred in the upper crown of trees in plots one to six in 1978, and new foliage formed in 1978 appeared sparce and shorter than normal (Fig. 2).

Compared to pre-outbreak years, average length of leader shoots was reduced notably in all plot areas during 1976, 1977, and 1978 (Table 3). This was to be expected because defoliation by the jack pine budworm is concentrated in the upper crown (Graham 1935) and can result in top-kill after one or two years of defoliation (Kulman 1971; Kulman et al 1963).

A visual inspection of trees surrounding each of plots one to six in 1978 indicated that top kill of 0.2 to 0.5 m was evident on an average of 20 per cent of all trees (range 10-50 per cent). However, no tree mortality was observed that could be attributed solely to budworm defoliation effects. Fig. 3 illustrates the general appearance of tree crowns at the end of the 1978 growing season.

In plot 7 a portion of the leader and some lateral twigs on one tree were killed in 1978, while the terminals of the other three trees were undamaged. At the time of examination in late August, all new shoots, foliage and terminal buds appeared healthy, and all four trees had first-year formed cones. However, light external feeding by budworm larvae had occurred on some female cones in 1976 and 1977.

In plots one to six, three of the sample trees had dead leaders in 1976, seven had dead leaders in 1977, and nine had dead leaders in 1978. All trees had some dead twigs and buds in the upper crown in 1978 and no staminate strobili (pollen clusters) or conelets were observed. Additionally, some trees had no second year cones in either 1977 or 1978, suggesting that the defoliation effects had disrupted male and female flower development, in addition to their destruction from larval chewing. Female cones formed in 1976 and 1977 were often damaged externally, stunted, and distorted as a result of larval feeding (Fig. 4). Other workers have reported similar feeding damage to the reproductive structures (Graham 1935; Heron 1956; Kulman and Hodson 1961; Kulman et al. 1963; Rauf et al 1985).

Radial Growth Defects

Profiles of annual radial increments at the different stem levels are plotted in Fig. 5, separately for trees from plots one to six and from plot seven. The two profiles are generally similar at each stem level, except for the 1978 increment of trees in plots one to six that reflect the more severe defoliation levels. Greatest magnitude of incremental growth is reflected in the upper crown levels where radial growth is often largest, and where sensitivity to defoliation effects is maximal (Kulman 1971). Both groups of trees show a declining trend in growth rate after 1975 at most stem levels except at the bh level where the downward trend is evident one year later. These differences are more strongly exemplified in Figs. 6-A, -B, which illustrate the radial growth pattern vertically on the stem for each year from 1973 to 1978. Graphs of both tree groups confirm there was no appreciable reduction in growth prior to 1977, except perhaps for small reductions at disc levels L-1 and L-2, the top two to three m of the crown. This suggests that light defoliation in the upper crown was likely occurring as early as 1973.

Average radial growth was reduced most in 1978, to less than 0.2 mm at all stem levels of trees in plots one to six, and to less than 0.1 mm at the L-1 and L-2 stem levels (Fig. 6-A).

Some difficulties were encountered when measuring the 1978 ring. On several discs, mostly from the upper crown, the 1978 ring was entirely missing or absent around part of the circumference (Fig. 7). This necessitated the tracing of "key indicator" rings that were usually identified as having a strong contrasting band of summerwood (e.g., Fig. 7, 1973 ring), and that could be recognized easily at most stem levels. Similar narrow and incomplete growth rings were observed in the 1966 and 1967 increments (Figs. 5, 7), likely as a result of an earlier jack pine budworm outbreak that extended from 1963 to 1967 in the Nisbet Provincial Forest (Anon. 1963-1969; Brandt and McDowell 1968). During that outbreak which peaked in 1965, at least two rings (1968 and 1969) were abnormally thin following the year of population collapse. The radial growth profile at bh level on trees from plots one to six (Fig. 8) suggests that growth recovery remained low in 1979, but that rapid recovery occurred in subsequent years, regaining near pre-outbreak (1970-1974) growth levels by 1983.

The likelihood of missing and partial rings in the upper stem during one or more outbreak periods precluded the use of the vertical growth sequence of Duff and Nolan (1953) to depict the effects of defoliation (Graham 1963; Kulman 1971). Additionally, the oblique sequence, as portrayed in Fig. 6-A, -B, provided a sure means of tracing missing or partial rings. This sequence also adequately portrays the extent of growth reduction due to defoliation throughout the entire stem (Graham 1963). The graphs indicate that growth reductions during 1977 and 1978 are fairly uniformally distributed along the stem at the lower level of defoliation (Fig. 6-B). In contrast, the higher level of defoliation (Fig. 6-A) caused a more uneven distribution of growth, and hence the intrinsic growth pattern was more drastically altered.

Radial Growth Pattern on Spruce and Larch

Radial growth measurements on white spruce and eastern larch both show increasing trends at least from 1967 to 1978 (Fig. 9), and thus help to substantiate the reduced growth on jack pine during 1975-1978 as due mainly to the effects of jack pine budworm defoliation. The reduced growth in the early 1960's on these species may have been partly climate related (see Fig. 10). However, it is worth noting that the low growth rate of eastern larch during much of the 1960's was likely due to defoliation effects of the larch sawfly, **Pristiphora erichsonii** (Hartig). This insect was reported causing moderate to severe defoliation in the Prince Albert vicinity annually from 1959 to 1966, and caused light defoliation again from 1967 to 1969 (Anon. 1960-1970).

Seasonal moisture in the Nisbet Forest was not likely a limiting factor to normal tree growth as suggested in Fig. 10, where an increasing trend in precipitation has continued since 1962.

Volume Loss Estimates

The estimates of average volume growth per tree for each annual conical shell of wood are summarized in Table 4. Compared to the mean annual volume during the pre-outbreak period, 1970-74, the volume estimates in plots one to six for 1975 and 1976 were both larger. However, a declining trend from 1975 onward is apparent in both tree groups, suggesting that some growth reduction likely occurred in 1976. Net volume losses were evident only in the 1977 and 1978 increments where maximum reductions of 91 per cent and 54 per cent occurred, respectively for the two tree groups. Measureable losses likely continued during at least two post-outbreak years (1979-1980) as suggested in Fig. 8. These volume loss estimates occurred on severely defoliated jack pine stands (plots one to six) where the incidence of top kill was relatively light (est. 20 per cent and where tree mortality was negligible. Seasonal drought conditions occurring during the same years could have increased the losses substantially. The estimated losses are compatible with those reported at other locations (Kulman 1971; Kulman et al 1963; Prentice and Nairn 1958).

While top kill and reduced radial increment have been the most common losses resulting from jack pine budworm defoliation (DeBoo and Hildahl 1968; Webb and Bean 1967) more severe losses of up to a third of the merchantable volume have been reported during individual outbreaks (Brandt and McDowell 1968; Clancy et al 1980; Howse 1984; Kulman et al 1963; Nyrop et al 1983).

The current study was limited to an evaluation of growth losses within the stems of defoliated trees. The data can, however, provide a basis for incorporating these losses with tree mortality, so that total volume loss estimates can be made on a stand basis that reflect an accumulation during the outbreak period and in the early post-outbreak years. Some attempts to evaluate losses on a stand basis for timber management planning include Nyrop et al (1983), Rose (1973), and Wotton et al (1978).

Additional impacts resulting from jack pine budworm defoliation include the development of crooked and multiple leaders (Howse 1984), changes in crown shape (Kulman et al 1963), and possible disturbance of various physiological processes such as carbohydrate dynamics (Ericsson et al 1980).

Acknowledgements

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Table 1. Summary of the characteristics of jack pine trees sampled for **C. pinus pinus** damage impact in the Nisbet Provincial Forest, Saskatchewan in 1978.

	No. of trees sampled	Av. tree height (m)	Av. tree diameter (cm)	Av. tree age	Av. length live crown (m)
Plots 1 to 6	12	11.9	12.9	55	6.91
Plot 7	4	12.3	13.3	49	6.89

Table 2. Summary of percentage defoliation caused by **C. pinus pinus** on jack pine trees, for 1976 to 1978 in the Nisbet Provincial Forest, Saskatchewan

	1976	1977	1978
Plots 1 to 6 (12 trees)	96	96	23
Plot 7 (4 trees)	50	77	11

Table 3. Summary of the average leader shoot lengths (cm) for the years, 1973 to 1978, of jack pine trees with defoliation caused by **C. pinus pinus**, Nisbet Provincial Forest, Saskatchewan

	1973	1974	1975	1976	1977	1978
Plots 1 to 6	24.5	21.3	27.0	15.2	4.6	2.6
Plot 7	21.0	22.0	22.0	15.8	10.7	7.5

Table 4. Estimated yearly increment volumes (cm^3) per tree on jack pine stems for a period preceding jack pine budworm defoliation (1970-1974) and during the outbreak years (1975-1978), Nisbet Provincial Forest, Saskatchewan

Plot sites sampled	No. of trees	Pre-outbreak yrs. 1970-1974	1975	1976	1977	1978
Plots 1-6:	12					
Av. volume/tree		2496	3359	2830	1334	236
Vol. range/plot		1333-3629	1992-4538	1816-3824	928-1674	131-491
% of pre-outbreak volume		—	135	113	53	9
Plot 7:	4					
Av. volume/tree		2511	3118	2691	1904	1159
% of pre-outbreak volume		—	124	107	76	46

LIST OF FIGURE CAPTIONS

Fig. 1. Study area in Nisbet Provincial Forest, Saskatchewan, showing the distribution of areas defoliated by the jack pine budworm and growth impact study plots in 1978.

Fig. 2. Upper shoots of jack pine showing first-year recovery from jack pine budworm defoliation.

Fig. 3. Defoliated jack pine stand typical of plot sites one to six in late August, 1978.

Fig. 4. Second year cones of jack pine with external feeding damage caused by jack pine budworm larvae.

Fig. 5. Average radial growth profiles at eight stem levels (L1 to L7, and BH), plotted separately for trees from plots one to six and from plot seven.

Fig. 6 -A, -B. Radial growths at different stem levels of the individual year increments, 1973 to 1978, plotted for trees from plots one to six (A) and for trees from plot seven (B).

Fig. 7. Radial section from the lower part of a severely defoliated jack pine stem showing partial rings (1966-1967) and narrow rings formed during 1966 to 1969 (previous outbreak period), and during 1977-78, part of the current outbreak period.

Fig. 8. Average radial growth pattern at b.h. level on jack pine trees selected from plots one to six, showing growth recovery during 1978 to 1984.

Fig. 9. Average radial growth pattern at b.h. from **Picea glauca** (Sw) and from **Larix laricina** (Le).

Fig. 10. Trend of seasonal precipitation, cumulated for the period April 1 to August 31, from 1958 to 1978. Data extracted from the nearest weather station at Prince Albert, Saskatchewan.

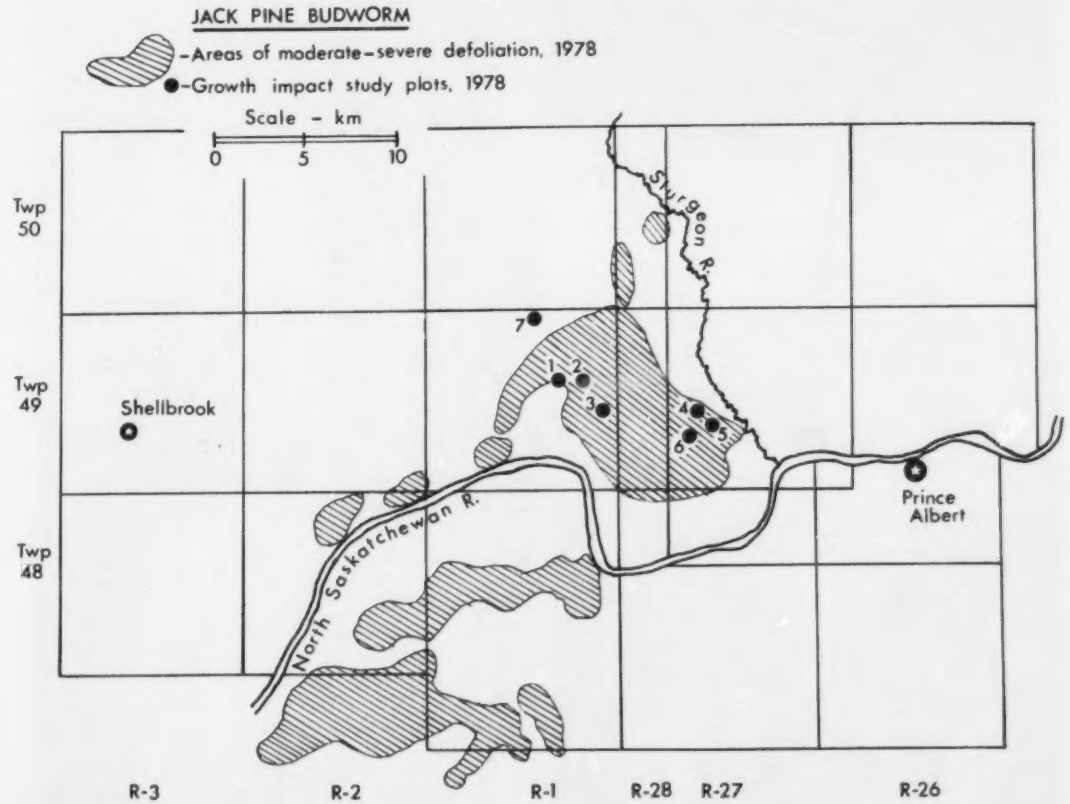
JACK PINE BUDWORM
-Areas of moderate-severe defoliation, 1978
-Growth impact study plots, 1978
Scale - km
0
5
10
Twp 50
Twp 49
Twp 48
Shellbrook
Sturgeon R.
North Saskatchewan R.
Prince Albert
1
2
3
4
5
6
7
R-3
R-2
R-1
R-28
R-27
R-26

Figure 1

1967
1966
1973
1978

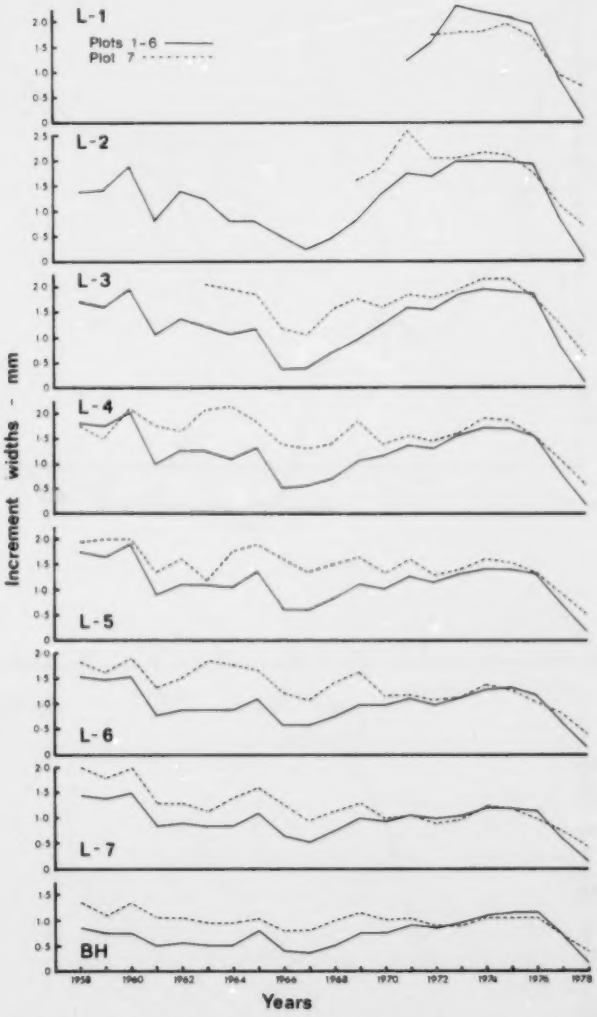
L-1
Plots 1-6
Plot 7
L-2
L-3
L-4
L-5
L-6
L-7
BH
Increment widths - mm
Years

Figure 5

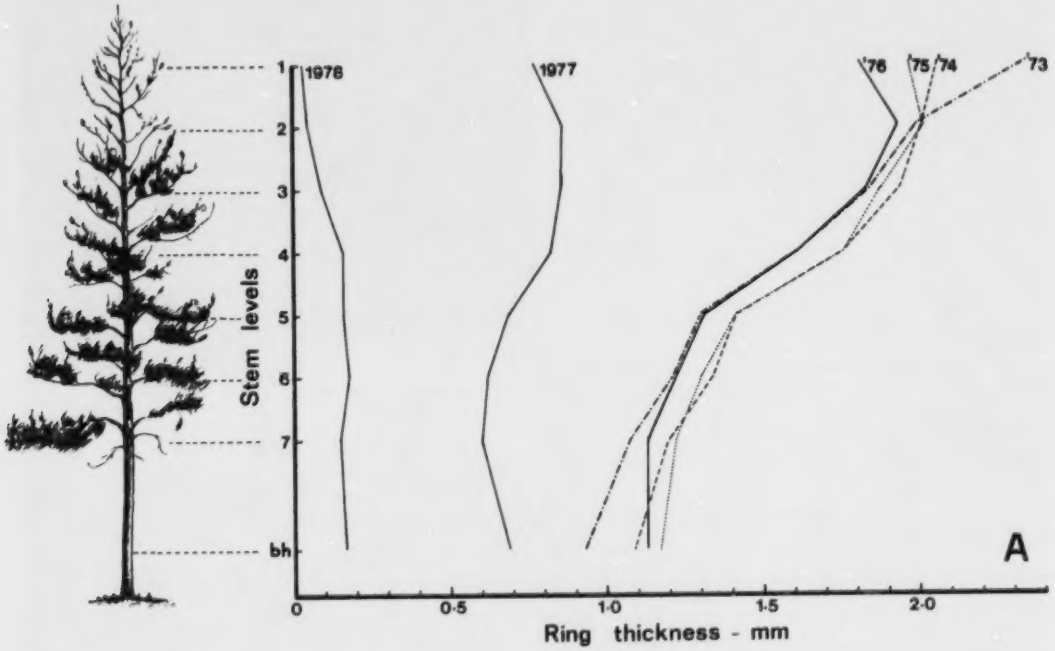

Figure 6-A

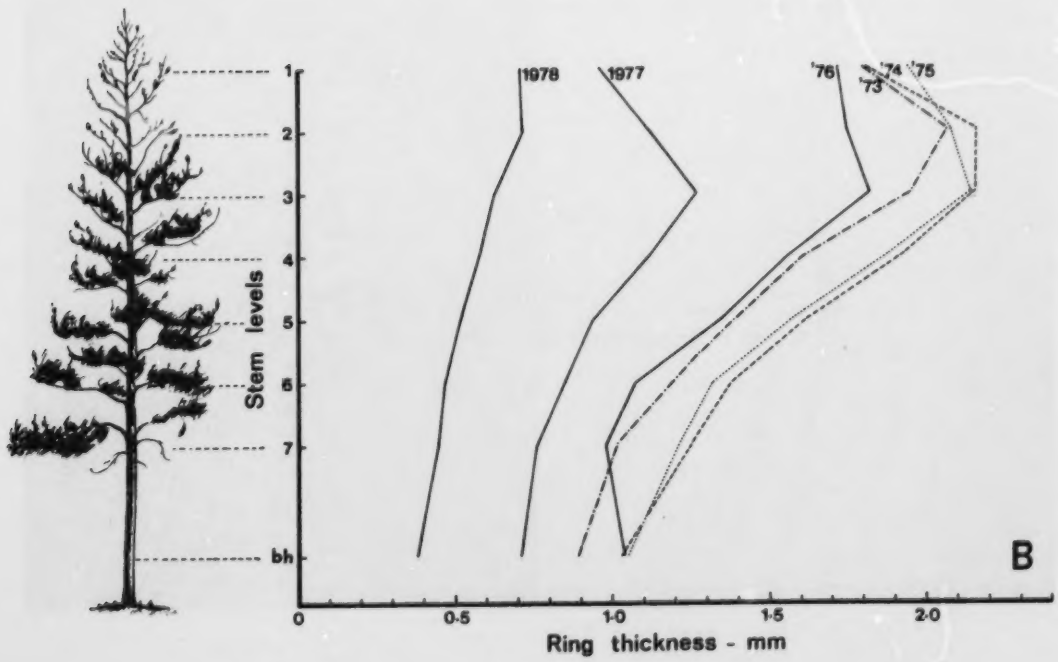

Figure 6-B

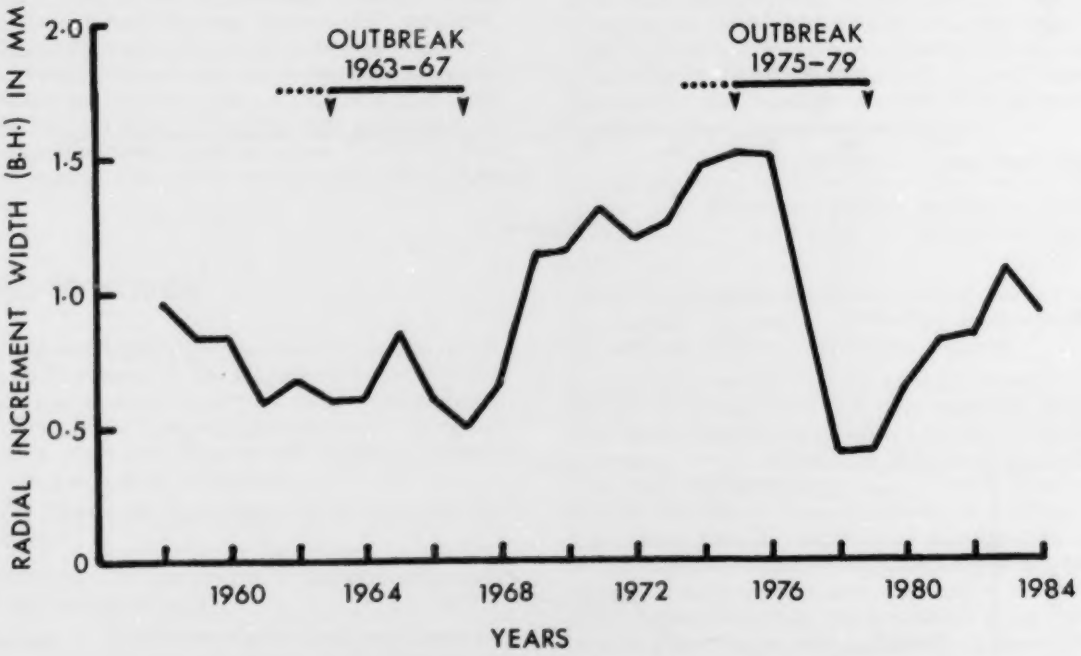
RADIAL INCREMENT WIDTH (B·H·) IN MM
2·0
1·5
1·0
0·5
0
OUTBREAK
1963–67
OUTBREAK
1975–79
1960
1964
1968
1972
1976
1980
1984
YEARS

Figure 8

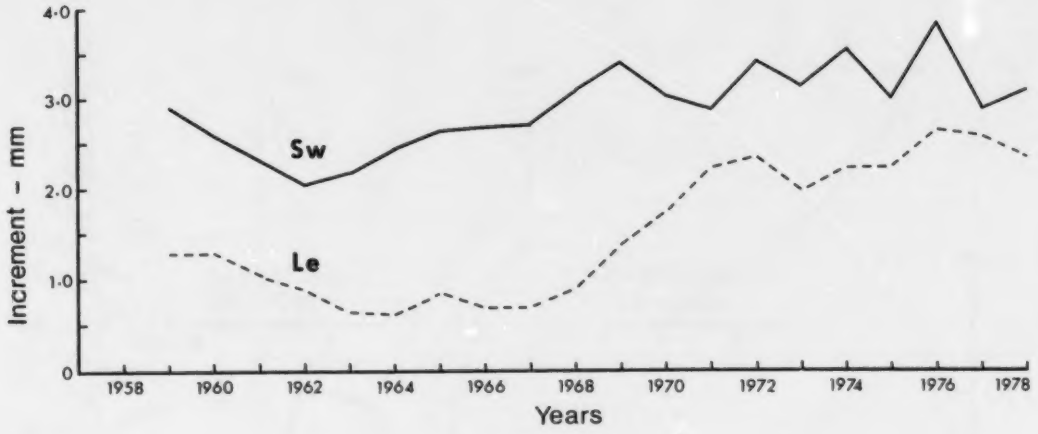

Figure 9

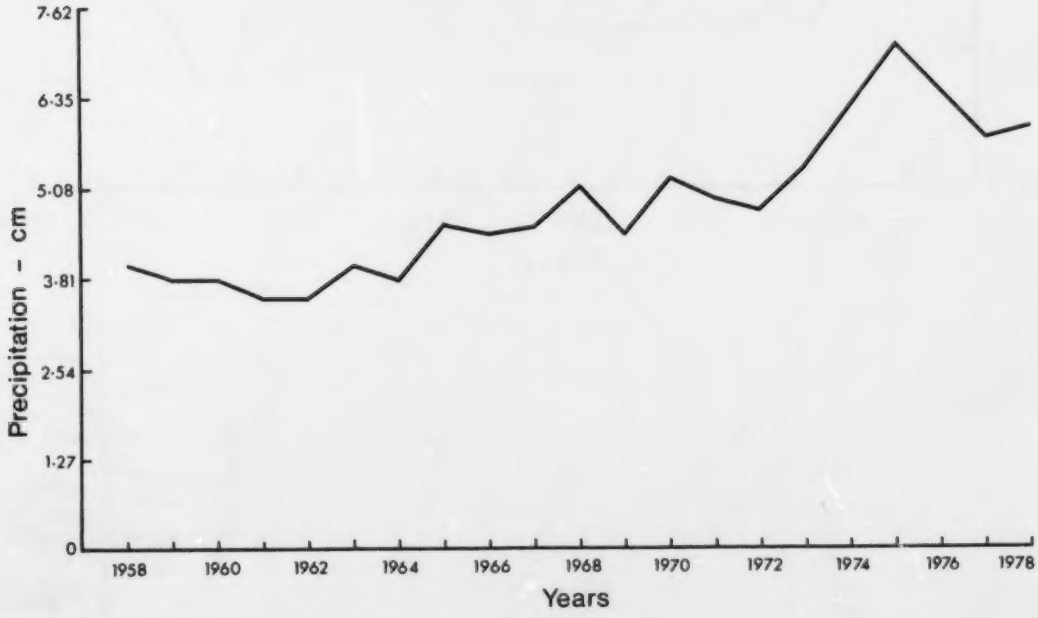

Figure 10

Jack Pine Budworm Egg Mass Survey Method

In 1985 the jack pine budworm ***Choristoneura pinus pinus*** *(Freeman) infestation in Manitoba expanded to a level never before recorded in the province. Aerial surveys conducted by the Canadian Forestry Service, Forest Insect and Disease Survey Unit, indicated 2,048,000 hectares of moderate to severe defoliation. FIDS infestation maps were made available to regional foresters for the priorization of jack pine stands within the infested areas. To predict 1986 defoliation, an egg mass survey was carried out by the Forest Protection Survey Unit within designated high priority areas.*

Field Methods

The sampling system used was similar to that developed by G. Howse of Great Lakes Forestry Centre. At each plot location six sample trees were selected. One 60cm. branch tip was collected from mid crown of each sample tree. At each site a general defoliation rating was done as follows:

Light — up to 35 per cent defoliation of the current shoots

Moderate — 35 per cent to 70 per cent defoliation of the current shoots

Severe — more than 70 per cent defoliation of current shoots and possible back feeding on previous foliage

Laboratory Methods

The examination of branch samples for egg masses and defoliation was done in the lab. Egg mass densities relate to the next year's defoliation as follows:

Light defoliation — one to two egg masses per plot

Moderate defoliation — three to five egg masses per plot

Severe defoliation — six or more egg masses per plot

Branch samples were assessed for feeding damage using 13 defoliation categories (similar to Fettes categories for spruce budworm). Giving consideration to the importance of staminate flowers on early larval survival, branches were assessed for flower bud production. The 10 most terminal buds were examined on each branch. Flower bud production was expressed as a percent of the total buds examined.

Risk Values

Utilizing the survey information a risk value was assigned to all sample areas. These risk values take into consideration 1985 defoliation, plus the prediction for 1986. The 1985 defoliation considers three sources of information; the FIDS aerial survey, general assessment at the plot location, and the sample branch defoliation. Risk values are as follows:

	1985 Defoliation	1986 Prediction
High	moderate - severe	moderate - severe
Medium	nil - light	moderate - severe
Low	—	nil - light

These ratings are based on the premise that jack pine can tolerate one year of moderate - severe defoliation without suffering irreparable damage.

A series of protection options were drawn up to deal with the expected 1986 jack pine budworm infestation. These options range from a maximum level of protection, which includes all jack pine stands (Net Operable I, II & III) in the jack pine working group with potential for harvest, to no protection with redirection of harvesting and/or accelerated salvage cuts. The various options are based on accessibility, site productivity, investments to date (plantation or silviculture treatment) and age class. A report of the results including risk values was submitted to the regional foresters, with the recommendation to consider the various protection options within the high and medium risk areas.

Problem Encountered

The survey methodology used in 1985 was done so with the knowledge that there are inherent weaknesses in the system. These include egg mass densities as they relate to the following year's defoliation, plus the information used in assigning risk values.

The egg mass survey conducted in 1984 in the Moose Lake area predicted 1985 defoliation to be well into the severe category. Based on these results, plans were made to spray 6000 ha. in 1985. By the time peak third to fourth instar was reached, during the prespray larval sample, populations had dropped to an average of 4.3 larvae per 60cm. branch tip. Assuming this number would result in light defoliation, in contrast to the expected severe, the spray project was cancelled. Aerial reconnaissance of the area following the feeding period, indicated generally light

defoliation with some localized moderate defoliation. The absence of male flowers (a major source of nutrition for young larvae) and cool moist weather throughout the larval feeding period are suspected factors leading to the population decline. Larval development was slower than normal, taking approximately six weeks from emergence to peak third to fourth instar.

The assignment of risk values was based on the premise that jack pine could withstand at least one year of moderate - severe defoliation, i.e., if an area experiences this level of defoliation and it is predicted to recur a second year, a high risk value is assigned. If management decisions are based on risk values (spray high risk areas) budworm impact information and defoliation rating methods require improvement. For example, impact data was collected in the Moose Lake area following two years of severe defoliation. Top-kill and tree decline was over 30 per cent in mature and overmature stands and approximately 20 per cent in immature stands. These differences suggest more impact information is required taking age, site and stand composition into account. It is quite likely risk values should not be the same for different site and age classes.

The method of assessing defoliation should be more precise as it is the major criteria used in assigning risk values. Three sources of information are used to determine defoliation; aerial surveys, ground surveys and actual branch defoliation. At present, aerial surveys conducted by FIDS use fire detection aircraft following a flight path predetermined by Fire Management staff. As a consequence, thorough coverage of infestations is lacking. A more intensive aerial survey is required. A defoliation assessment is made from the ground during the egg mass survey. This method is very general and becomes somewhat subjective. A more systematic approach is needed. For the 1986 survey the six sample plot trees will be rated individually, likely assessing defoliation by crown levels.

Pheromone Trap Surveys

Jack pine budworm pheromone lures were set out at 12 locations throughout the range of jack pine in Manitoba. The plot locations are intended to be permanent for annual monitoring of budworm populations. Both the lure itself and the plot design were developed by the Research and Productivity Council. Pherocon 1C sticky traps were used to contain the lures. Using three concentrations of the pheromone (.003, .03, .3) two grid pattern plots were established at each location. Spacing between lures, within a plot, was 40 metres. The two plots were separated by a distance of at least 80 metres. The greatest moth capture at 10 of the 12 locations was achieved with the .03 concentration of the pheromone.

Using the same pheromone concentrations and plot design, lures were set out in Multi-pher traps at three of the locations. Multi-pher are non-saturating traps using Vapona for moth kill. These traps had consistently lower moth captures at all concentrations than the Pherocon 1C sticky traps. Moth capture was again greatest with the .03 concentration.

Current Jack Pine Budworm Research in Manitoba

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The principal objective of the Canada/Manitoba Forest Renewal Agreement, and the Memorandum of Understanding between the Canadian Forestry Service and Manitoba Natural Resources, "is to enhance the contribution of the forest research program of the Canadian Forestry Service to the management of the forest resource in Manitoba". Further, "the Canadian Forestry Service will develop its capability in research, development, and technology transfer in . . . , insects and diseases," and "the primary client for federal research in Manitoba is the provincial government and the principal effort of a research and development program will be directed to forest protection, forest management and renewal needs of the province."

It is clear from this mandate and a perusal of the Forest Research Plan For Manitoba that a pest management plan which could be integrated into the province's forest management plans is required. Therefore, we have initiated studies which will evaluate, and modify if necessary, the pest surveys which are currently conducted. Much of the effort, however, is being directed to studies which will provide the basic information on which pest management plans can be developed.

As an example, one of the surveys which will be examined to evaluate the quality of information produced and its utility in pest management systems is the annual aerial defoliation survey of forests affected by the jack pine budworm. Aerial defoliation surveys are the only means currently available to assess the extent of outbreak populations. In Manitoba, the aerial survey is also used in locating plots in which egg mass collections are to be made. Results of the egg mass surveys are combined with the aerial defoliation surveys to identify forest stands which will be considered for treatment in the followinng season. Aerial defoliation surveys are, therefore, important tools in the management of jack pine budworm populations in Manitoba. Aerial surveys are not without problems, however.

The extensive forested area in Manitoba, coupled with limited budgets for pest management, severely limit the proportion of this area that can be covered by these surveys. Figure 1 clearly indicates the extent of coverage achievable with the resources currently available for aerial surveys. A large proportion of the area affected can not be examined with the current level of effort. Without an increase in the level of effort, alternative approaches will have to be developed.

One approach is to relax the requirement that the aerial survey be expected to provide a census of the forest stands affected. This would entail that a sampling system be instituted in place of the current survey procedure. Areas to be surveyed would be selected on the basis of criteria that are established by the various agencies which use this information. For instance: forest cover type, stand value, stand age, ecological, and other biological information could be combined with other managerial information to establish priorities for areas to be surveyed. Flight lines could then be established to optimize the utility of the survey for a given budget.

A second opportunity is presented with the use of remote sensing technologies. Recent studies with airborne systems suggest that the M.I.E.S. system using the push broom scanner may be of some value in providing the coverage necessary to provide the census which the aerial surveys are unable to provide with current budgets. Other opportunities are presented by satellite imagery that may be incorporated in the surveys currently conducted. The utility of these systems have serious drawbacks in that cloud cover interferes with the images produced. In the case of satellite imagery it is possible to have the area of interest obscured on several successive passes of the satellite, as happened in southern Manitoba this summer. Depending on the eventual costs and the operating characteristics of these systems, they may become useful complements to the defoliation surveys currently conducted.

A further refinement of the aerial surveys as they are currently conducted is possible by modifying the way in which observations are recorded. The installation of a Geographic Information System (G.I.S.) in Manitoba provides an opportunity to integrate survey information with other forest inventory information. This has the potential of providing the resource manager with information within days of the defoliation surveys'

completion. More importantly, this course would allow the resource manager to integrate this information with other data that can only be done with extreme difficulty at present. Depending on the manager's priorities, updates to management plans and other related decisions could be made with better information which could be available in a much shorter period.

Impact Studies

In developing pest management systems for the jack pine budworm, we have chosen to focus on developing methods to predict the long- and short-term impacts of this insect on forest resource values. In doing this, we developed a hypothetical model of jack pine budworm impact trajectories which was adapted from models initially developed for the spruce budworm by MacLean (1981). Figure 2 is an attempt to describe the functional relationships between jack pine budworm populations and the physical impacts of their feeding. Studies are being conducted which will determine the parameters of the impact and population curves.

Specific studies are identified in the lightly outlined boxes of Figure 3. These studies are now underway in Manitoba to provide the basic information on which to base pest management systems. In addition to providing the data on which to calibrate the impact curves, they will also provide the information to design survey, monitoring, and evaluation procedures. However, the design criteria for these procedures can only be specified once a fairly good understanding of the biological and socio-economic characteristics of the system has been obtained. Thus some effort will have to be invested in synthesizing the information from the basic studies into descriptions of insect population dynamics and the dynamics of the forest stands. These descriptions will be made sufficiently flexible to allow the evaluation of a variety of treatment options by forest managers who use the prediction models to be developed.

Long-term impacts are impossible to observe over the relatively short period for which the current agreement is in effect. However, there is a considerable volume of historical information which may be examined to describe the long-term behavior of the jack pine budworm in this region. The analysis of the Forest Insect and Disease Survey (F.I.D.S.) data collected over the past 50 years present an opportunity to investigate the fluctuations of jack pine budworm populations over this period. The annual defoliation surveys coupled with tree ring records can provide detailed information on the characteristics of defoliation on individual tree growth in this period. Tree mortality rates, and ultimately volume losses, can be determined from information on permanent sample plots which were established over the past 50 years. Similarly, phenological and climatological records can be analyzed to develop hypotheses about insect development and the severity of defoliation over this period.

We are currently evaluating the integrity of the historical records to determine their utility in describing the long-term behavior of the jack pine budworm in this region. Part of the effort, in the new field studies now under way, is directed to guiding us as to how best to interpret the information recorded in the past. Although some analysis of the historical record can now proceed, some investigations will have to await results of some studies presently in progress.

Insect population studies now underway are designed to describe the spatial and temporal distribution of the insects' various life stages within jack pine stands. In the short-term, these studies will provide information which can be used in designing sampling procedures for jack pine budworm population densities. At the end of the project, it is hoped that these studies will also provide some insight into the processes which influence population trends. More importantly from the impact standpoint, is that the relationship between insect numbers (and insect feeding) and tree growth-loss will be better understood. By including stands with low populations among the study sties, it is hoped that the full cycle of an outbreak can be described so that the most opportune time to intervene by controling insect damage can be identified.

Insect feeding and tree defoliation studies are being conducted to determine how to measure defoliation and, ultimately, how defoliation is linked to growth-loss and increased risk of tree mortality. Both observational and experimental approaches are being used to identify factors which control the severity of defoliation and individual tree growth-loss.

Tree growth-loss and tree mortality studies are now underway in stands of various ages and on different sites which have experienced different defoliation histories. These studies are intended to determine the response of jack pine stands to defoliation. A secondary function of these studies is to obtain basic information which will permit the design of operational surveys to evaluate impact on stands throughout the region.

An over-riding principle in designing these studies has been that the information provided can be integrated into models that will ultimately be used by resource managers. The models that will be derived from these studies will attempt to simulate aspects of the population dynamics of the jack pine budworm and the dynamics of jack pine stands. These models should be sufficiently flexible to permit the evaluation of different treatment effects and provide managers the tools with which to make informed decisions about jack

pine budworm treatments in stands currently managed. With these requirements it is imperative that the resource manager be included in the process of developing these models.

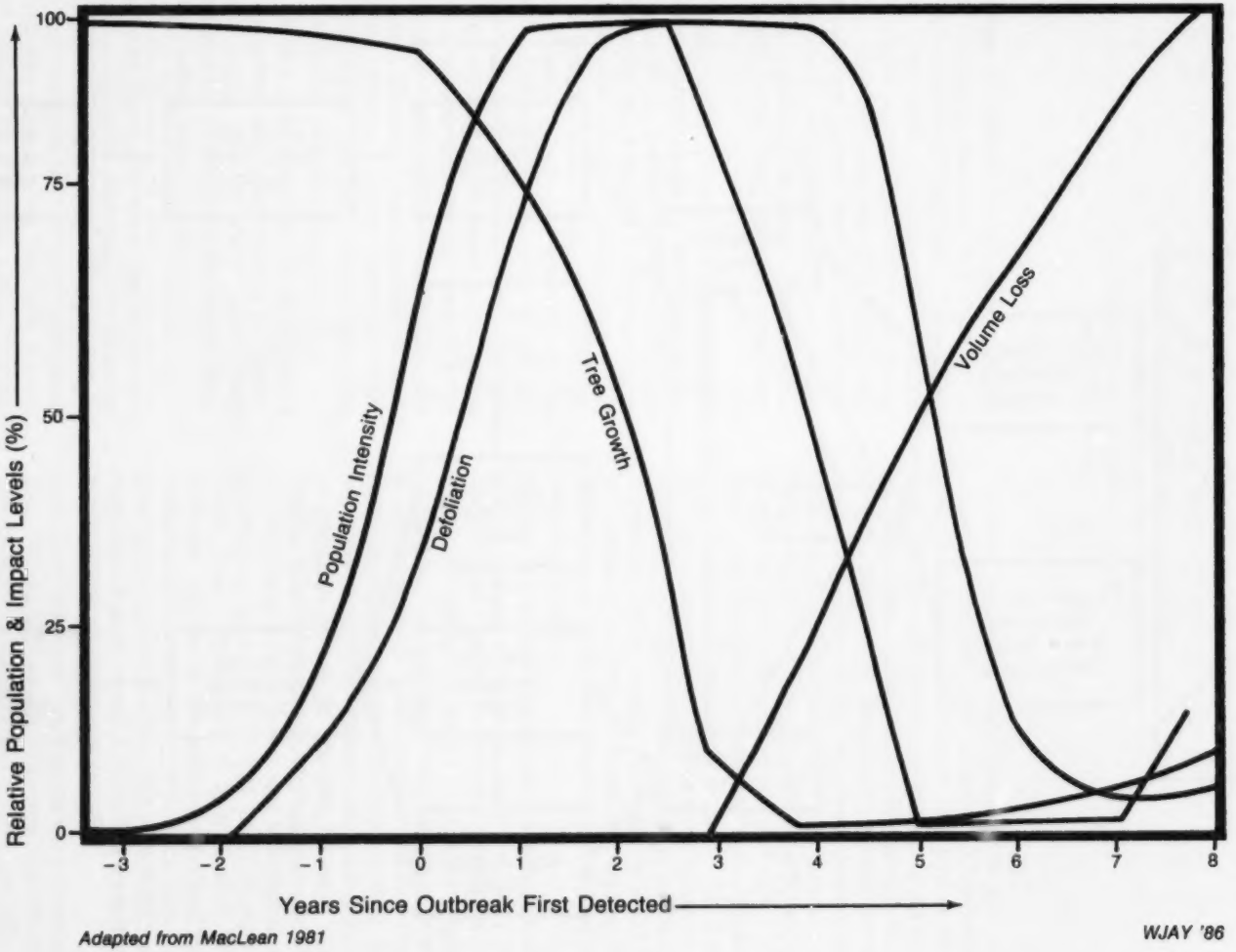
Reference

MacLean, D. A. 1981. Impact of defoliation by spruce budworm populations on radial and volume growth of balsam fir: a review of present knowledge. Mitt. Forstl. Bundes. Wien 142:293-306.

Figure 1
Aerial Survey Flight Routes
1985

Forest Insect & Disease Survey
Canadian Forestry Service, Winnipeg

Hypothetical Jack Pine Budworm Impact Trajectories



Adapted from MacLean 1981

WJAY '86

Figure 2

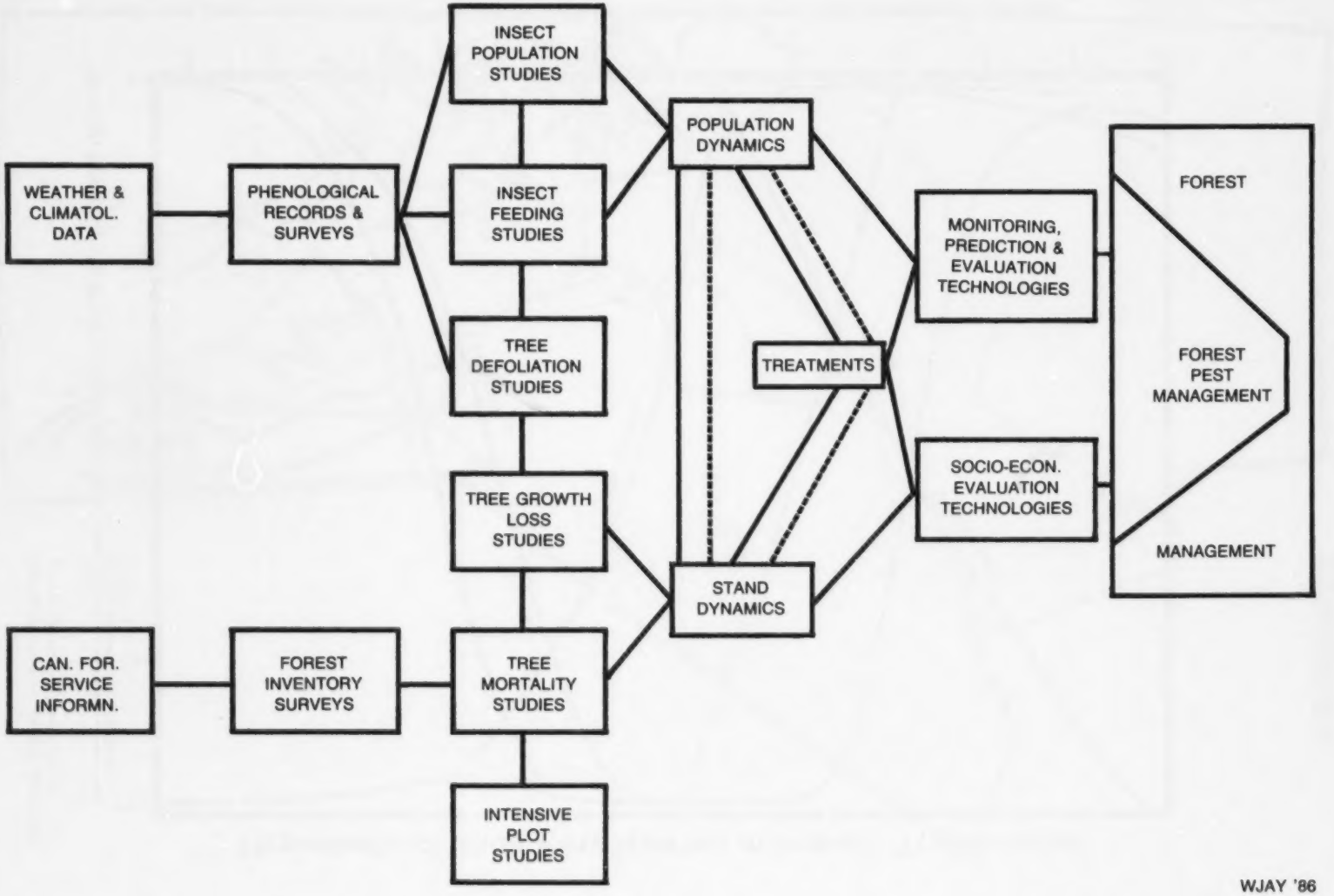

INSECT POPULATION STUDIES
WEATHER & CLIMATOL. DATA
PHENOLOGICAL RECORDS & SURVEYS
INSECT FEEDING STUDIES
TREE DEFOLIATION STUDIES
TREE GROWTH LOSS STUDIES
CAN. FOR. SERVICE INFORMN.
FOREST INVENTORY SURVEYS
TREE MORTALITY STUDIES
INTENSIVE PLOT STUDIES
POPULATION DYNAMICS
STAND DYNAMICS
TREATMENTS
MONITORING, PREDICTION & EVALUATION TECHNOLOGIES
SOCIO-ECON. EVALUATION TECHNOLOGIES
FOREST
FOREST PEST MANAGEMENT
MANAGEMENT
WJAY '86

Figure 3

Jack Pine Budworm in Ontario

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Jack pine (**Pinus banksiana** Lamb). is one of the major species in Ontario's forests. It is considered to be a tree of the boreal forest region and characteristically grows in pure stands or in a mixture with black spruce (**Picea mariana** [Mill.] B.S.P.). It is also found in mixed conifer - hardwood stands with white spruce (**Picea glauca** [Moench.] Voss), black spruce, balsam fir (**Abies balsamea** [L.] Mill.), trembling aspen (**Populus tremuloides** Michx.) balsam poplar (**Populus balsamifera** L.) and white birch (**Betula papyrifera** Marsh.).

In the boreal forest region of Ontario, which is roughly approximate to the Northwestern, North Central and Northern regions of the Ontario Ministry of Natural Resources (OMNR), black spruce comprises about 50 per cent of the total volume of wood, poplar about 19 per cent and jack pine about 15 per cent. However, on a commercial basis, jack pine is considered to be the second most important tree species in northern Ontario. Jack pine is most abundant in northwestern Ontario where it reaches its best development on the sandy soils in a wide area north and west of Lake Superior. In general, volumes tend to decline towards the east and south, although several districts in northeastern Ontario, namely, Kirkland Lake, Timmins, Gogama and Chapleau have proportions of jack pine higher than the boreal regional average.

The volume of jack pine harvested in recent years from Crown lands has ranged from five to 5.7 million cubic metres annually. This represents about 31-32 per cent of the total volume of wood harvested annually from Crown lands. About 77 per cent of the allowable annual cut for jack pine was utilized in 1977-1978 and this figure is probably more than 80 per cent today. While accurate data describing the extent of jack pine regeneration within the province is difficult to obtain, approximately 55,000 - 60,000 ha are planted or seeded directly each year. Undoubtedly a much larger area of variable but unknown size is regenerated naturally each year as the result of fires or harvesting. Whether or not natural regeneration is satisfactory, in terms of stocking and other factors may be a question, but the important point is that there is a large amount of immature jack pine in plantations or natural stands throughout northern Ontario.

The most important insect problem of jack pine in Ontario is the jack pine budworm (**Choristoneura pinus pinus** Free.). In Ontario, jack pine is the principal host tree attacked by the budworm but red pine (**Pinus resinosa** Ait.), Scots pine (**P. sylvestris** L.) and eastern white pine (**P. strobus** L.) are also damaged. In the 1930's and 1940's this insect was considered to be the spruce budworm and was reported in the literature and Forest Insect and Disease Survey (FIDS) reports as "budworm feeding on pine". In the early 1950's, the two insects were considered separate species primarily on ecological grounds. As a consequence, however, there may be some doubt as to the reliability of information in reference to species, area infested and so on, in early FIDS reports (1937-1950). Nevertheless, using the information published in FIDS reports since 1937, the following infestation history can be assembled.

Sizable infestations have occurred frequently in one part of Ontario or another since the early 1930's (Table 1 and Figures 1-33). Interspersed among the short-lived infestations were two particularly extensive and destructive outbreaks that occurred over much of northwestern Ontario between 1936 and 1942 and again shortly afterwards from 1945 to 1948. Severe infestations were also reported from southern Ontario, around Midhurst and St. Williams, between 1940 and 1942. A short-lived, small outbreak occurred in 1954 in northwestern Ontario and was followed some five years later by a period (1959-1965) of numerous, small, local infestations in northwestern Ontario. However, another severe outbreak occurred between 1966 and 1973 when heavy infestations damaged jack pine stands in northwestern and southern Ontario. A maximum area of nearly 2.25 million ha was moderately-to-severely defoliated in 1967.

Jack pine budworm populations were generally low from 1974 to 1981 except for an upsurge in the Kenora area in 1979 which subsided quickly. In 1982, population increases became evident in the Georgian Bay (Lake Huron) area of southern Ontario where several infestations totalling 1,000 ha were detected and mapped. In 1983, moderate-to-severe defoliation totalling 67,000 ha was mapped in Quetico Provincial Park in northwestern Ontario, in northeastern Ontario

between Sault Ste. Marie and Sudbury and along the eastern shore of Georgian Bay in southern Ontario. Population buildups were reported from a number of other locations. In 1984, the infestations in northwestern and northeastern Ontario expanded dramatically, accounting for most of the 1,150,158 ha of defoliation mapped that year. Overall, this past year, 1985, saw a three-fold increase in the extent of moderate-to-severe defoliation to some 3,660,000 ha. Large expansions occurred in the previous years infestations in northwestern, northeastern and southern Ontario. Overall, at the current time, damage is light and consists largely of low levels of tree mortality and top kill in stands infested in 1984 or earlier. However, in two situations, Quetico Provincial Park and Georgian Bay, with infestation histories of two and/or three years, damage extends over 35,000 - 40,000 ha with up to 30 per cent dead trees and 40 per cent dead tops.

Forecasts for 1986 based on egg-mass surveys in August, 1985, are quite interesting in that population levels have declined nearly 60 per cent. The insect will continue to cause damage in numerous local situations throughout the 1985 infestation area, however, there is also potential for widespread population collapse, particularly in northeastern and southern Ontario.

Spraying operations totalling almost 6,100 ha were conducted by OMNR in 1968 and 1972 for the purpose of protecting high value areas such as provincial parks, plantations and stands of high quality timber. Canadian Forces Base, Petawawa, and most of the pine plantations at Petawawa National Forestry Institute were sprayed by the CFS in cooperation with the OMNR in 1969. Fenitrothion was used in 1968 (6 oz/ac.), 1969 (4 oz/ac.) and Zectran in 1972 (1.2 oz/ac.). During these years, several spraying operations were cancelled due to population collapse or populations materializing that were much lower than expected.

Damage is caused by the larvae feeding mainly on new growth. They prefer ♂ flower clusters but consume new foliage readily. Larvae are wasteful feeders. If severe attack is repeated for two consecutive years or more, trees will die; however, top-killing, crooked or multiple leaders, and increment reduction are more common. Damage is seldom quantified except in very general or broad terms. In 1971, fully stocked stands of pole-sized jack pine on generally good sites near Lake Traverse, Algonquin Park District, suffered 25 per cent mortality and 30 per cent top kill following light defoliation in 1967 and moderate-to-severe in 1968 and 1969. More severe damage can occur in low-density stands of large-crowned, flowering trees or in intermediate or suppressed trees of low vigor. More information is badly needed relating damage/impact to such variables as insect population levels, site, stand composition and environmental factors.

Research currently underway with jack pine budworm in Ontario includes population dynamics, parasites, development of sampling and predictive systems, direct control involving aerial application of insecticides (including chemicals, *B.t.* and virus), damage and impact, resistant trees and remote sensing.

There are a number of questions involving jack pine budworm, outbreaks and the resource that could be affected that need to be addressed:

1. How and why do outbreaks begin and collapse?
2. The beginning and collapse of outbreaks is apparently very abrupt — is this true and why?
3. Role of natural mortality factors (parasites, diseases, etc.)?
4. Role of staminate flowers?
5. Influences on production of staminate flowers (drought, insect defoliation, etc.)?
6. Significance of moth flights?
7. Population levels and damage (impact) of the insect in relation to individual tree or stand characteristics including age, height, species, species composition, site and environmental factors?
8. When is protection required; ie after first year of severe defoliation or later?
9. How long will protection be required?
10. Economics of protecting jack pine?

Some conclusions or comments in relation to the foregoing questions are listed in the following:

1. In order to prevent significant damage, one should protect (intervene) before the second year of severe defoliation occurs.
2. Population collapses may occur following two years of severe defoliation.
3. Based on historical records (maps and data), there appears to be great change from year to year that is difficult to predict. Infestation buildups appear to be rapid in all cases with declines occurring as abruptly as buildups in the 1940's and 1950's, but not as abrupt in the 1960's and 1970's. Infestation declines in recent years (1960's and 1970's) appear to persist longer than in earlier years. This persistence may be an artifact of the maps or mapping procedures as well as the possibility of mistaken identity in the earlier years.
4. Based on 50 years of records (1936-1985), it appears that five or six outbreaks have occurred leading to the conclusion that outbreaks occur every eight to 10 years on the average. Outbreaks

generally last only two to four years in a given location and the period between outbreaks ranges from one to two years to nine to 10 years.

5. It appears that in recent years damaging outbreaks are more likely to occur in northeastern and southern Ontario than 30 or 40 years ago. The current outbreak in northeastern Ontario is unique in view of its location and extent. This had not occurred previously (at least within the last 50 years).
6. Northwestern Ontario has consistently been the site of large, widespread and damaging outbreaks usually in conjunction with similar situations in Manitoba and Minnesota.
7. The dynamics of this insect appears to be closely related to or influenced by the weather; *ex* effect of weather on the host (drought, male flowers) and on the insect (moth flights).

The author wishes to acknowledge the contribution of E. J. Czerwinski, District FIDS Ranger, who prepared the infestation maps accompanying this paper.

Table 1. Annual area infested by jack pine budworm in Ontario, 1937-1985.

Year	Area (ha)	Location
1937	2,379,442	Northwest
1938	5,215,381	Northwest
1939	2,648,146	Northwest
1940	960,510	Northwest and southern Ontario
1941	1,531,160	Northwest and southern Ontario
1942	1,531,160	Northwest
1943	0	
1944	0	
1945	109,503	Northwest
1946	854,005	Northwest and northeast
1947	293,552	Northwest
1948	1,591 747	Northwest and northeast
1949	3,600	Northwest
1950	600	Northwest
1951	500	Northwest
1952	0	
1953	1,295	Northwest
1954	43,850	Northwest
1955	0	
1956	0	
1957	0	
1958	0	
1959	13,450	Northwest
1960	25,641	Northwest
1961	267,054	Northwest
1962	83,740	Northwest
1963	12,691	Northwest
1964	24,864	Northwest
1965	35,742	Northwest and northeast
1966	1,295,000	Northwest
1967	2,247,964	Northwest, northeast and south
1968	1,853,166	Northwest, northeast and south
1969	206,814	Northwest, northeast and south
1970	153,676	Northeast and south
1971	78,616	Northwest, northeast and south
1972	29,450	South
1973	18,100	South
1974	0	
1975	0	

Table 1. Annual area infested by jack pine budworm in Ontario, 1937-1985 *(continued)*.

Year	Area (ha)	Location
1976	0	
1977	0	
1978	0	
1979	0	
1980	0	
1981	0	
1982	1,000	South
1983	67,142	Northwest, northeast and south
1984	1,150,158	Northwest, northeast and south
1985	3,660,069	Northwest, northeast and south

Jack Pine Budworm in Ontario: — Egg-Mass Surveys — Staminate Flowers — Future Plans

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Egg-Mass Surveys

The ability to accurately forecast expected defoliation levels in specific areas is essential if effective protection strategies are to be developed against the jack pine budworm. This information must be made available with sufficient lead time to allow for the development of aerial spraying programs if required. We must, therefore, rely on egg-mass surveys or overwintering larval surveys for this information.

During the last major jack pine budworm outbreak in Ontario in the late 1960's and early 1970's, survey techniques were developed to monitor budworm populations and forecast defoliation. G. M. Howse, (Sippell, Gross and Rose, 1968) developed forecasts based on the total number of egg-masses found on six 60 cm (24 in) branch tips sampled from the mid-crown area of six trees (one branch per tree). Survey data suggested that counts in excess of eight (per six branch sample) could result in severe defoliation, three to eight egg-masses moderate defoliation and less than three egg-masses light defoliation. Field observation over the next few years resulted in the revised jack pine budworm forecast table presented in Table 1.

In 1982, a resurgence of jack pine budworm populations prompted the Ontario FIDS Unit to conduct egg-mass surveys at a number of locations in the province using the method described above. These surveys were continued the following year and in 1984, jack pine defoliation rates were determined at 41 of these locations. Analysis of the data indicated a good index of correlation ($r^2 = .7$) between the total number of egg-masses observed on six branches in 1983 and defoliation in 1984. The resultant nonlinear regression is presented in Figure 1. The same process was repeated in 1985 using egg-mass density and defoliation data from 123 locations. The data was categorized as to number of years infested (one, two or three) and subjected to the same analysis. The scatter diagrams, as presented in Figure 2, indicate an extremely variable relationship existed between egg-mass densities (1984) and defoliation (1985) with no significant correlations in any category. The reasons for this extreme variability are not known but may, in part, be related to the unusually cool and wet weather conditions during the summer of 1985. These generally unfavourable weather conditions for the jack pine budworm may have resulted in less consistent larval survival and, consequently, increased variability in defoliation.

Table 1. Jack pine budworm: Jack pine defoliation forecasts based on egg-mass densities.

Total egg-masses on six 60 cm branch tips (year x)	Defoliation forecast (year x + 1)	Defoliation (%) (year x + 1)
0	0	0
1-2	Light	1-25
3-5	Moderate	26-75
6+	Severe	76+

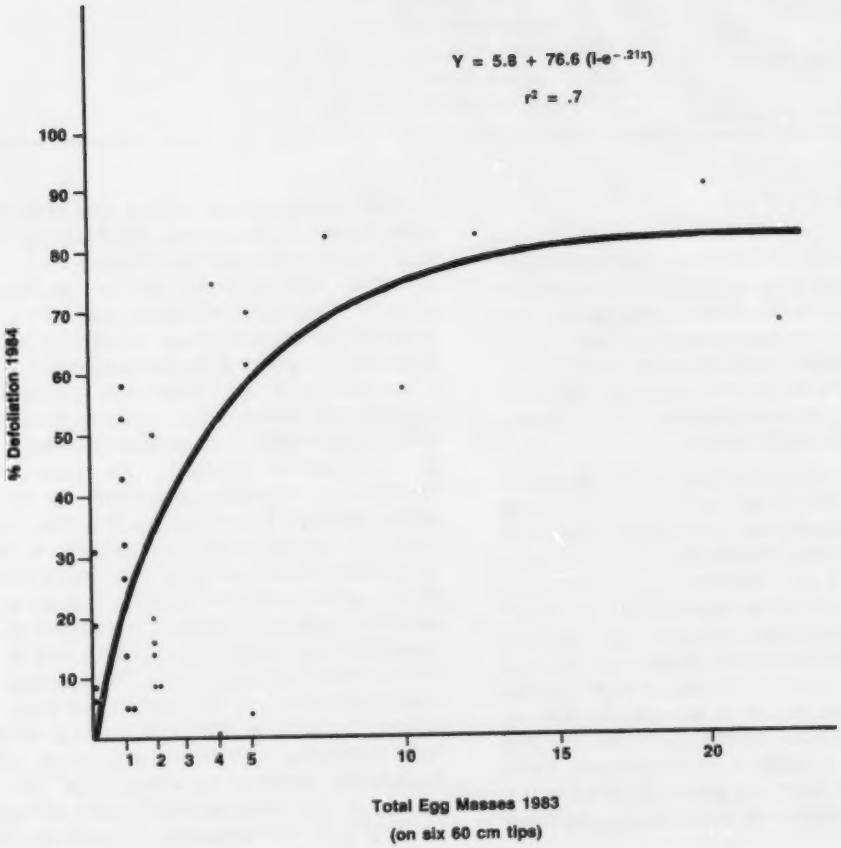

Figure 1. Jack pine budworm: Egg-mass densities in 1983 and subsequent jack pine defoliation in 1984.

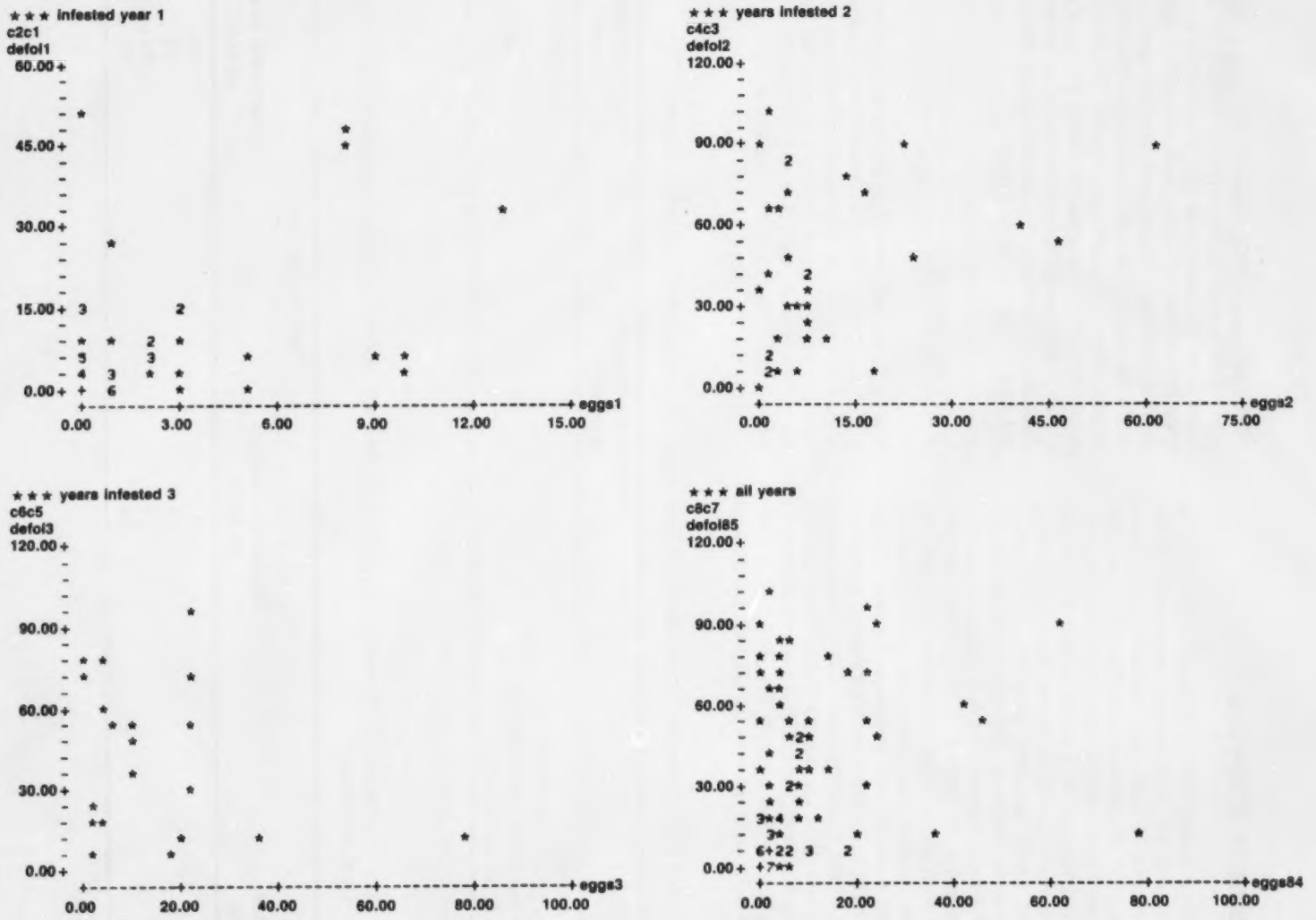

Figure 2. Jack pine budworm: Egg-mass densities in 1984 and subsequent jack pine defoliation in 1985 in areas infested for one, two and three years.

Staminate Flowers

A number of studies have suggested a strong correlation between the abundance of staminate flowers and increases in jack pine budworm populations (Lejeune 1950, Batzer and Jennings 1980). In 1985, surveys were conducted to determine budworm populations and damage on a large number of jack pine in northeastern Ontario to assess the efficacy of the provincial aerial spraying program. Observations made on some 240 trees; 127 with staminate flowers and 113 without, are summarized and presented in Tables 2 and 3. In Table 2, it can be seen that the average early instar larval population on trees with staminate flowers was more than double that observed on trees without staminate flowers. Consequently, defoliation rates were somewhat higher (17 per cent on the flowering trees. These observations support earlier findings, but the slightly lower survival rate of the larvae on trees with flowers is contrary to previous studies that suggest the presence of male flowers would enhance survival (Batzer & Jennings 1980). Lejeune (1950) observed that jack pine budworm larvae feeding in staminate flowers remained there until the fourth and fifth instar when they migrated to the new foliage. Since most of the damage is done in the later instars, branches with and without staminate flowers, but with similar larval populations, should suffer similar defoliation levels. This is supported by the data presented in Table 3. The slightly higher defoliation rates recorded on the branches with flowers may be due to the generally smaller size of the new shoots on these branches.

Future Plans

In conjunction with the anticipated aerial spraying programs against the jack pine budworm, surveys will be conducted to monitor insect populations and assess damage. Relationships among egg-masses, larvae, staminate flowers, tree size and defoliation will be examined to develop better predictive tools.

Table 2. Jack pine budworm: Observations on jack pine with and without staminate flowers.

	Staminate flowers present	Staminate flowers absent
Number of trees	127	113
*Average larvae per 60 cm tip	17	8
Average defoliation (percentage)	56	39
Larva to adult survival rate	.176	.191

*Third and fourth instar larvae

Table 3. Jack pine budworm: Defoliation rates on jack pine with and without staminate flowers at increasing larval populations.

	Defoliation (%)	
Larvae per 60 cm tip	Staminate flowers present	Staminate flowers absent
1-10	41	35
11-20	59	55
21-30	76	64
31 +	84	79

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Jack Pine plantations, outbreaks of Jack Pine Budworm, birds, and mammals, and impacts of *Bacillus thuringiensis (B.t.)*, Matacil, and Fenitrothion

by
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We seek to explain the causes of density of key species of wildlife. Since 1979, we have censused birds and mammals and conducted detailed studies of population dynamics of Spruce Grouse in plantations of Jack Pine near Gogama, Ontario. In 1985, there was an outbreak of Jack Pine Budworm and operational and trial spraying of the insecticides: ***Bacillus thuringiensis (B.T.)****, Matacil, and Fenitrothion. We monitored the effect of the insecticides on birds, mammals, amphibia, and arthropods of shrubs, herbs, and forest floor. Spruce Grouse, Nashville Warbler, Varying Hare, and Heather Vole were in unusually high density in some plantations before 1985, suggesting plantations or monoculture forests cause outbreak populations of some species. A number of birds and one species of mammal increased greatly in abundance in 1985 and may have responded as predators of the budworm. They were the warblers: Blackburnian, Bay-breasted, Ovenbird, Nashville, and Yellow-rumped; and the White-throated Sparrow and the Masked Shrew. The insecticides have not apparently affected the numbers of birds and small mammals. All except Matacil may have decreased the Wood Frog. From preliminary analysis, among eight groups of arthropods, Fenitrothion depressed four;* ***B.t.****30, two;* ***B.t.****20, one, and Matacil zero. We need to know how outbreaks can be stopped before they start.*

Introduction

Our purpose is to: 1) show that some species of birds and mammals are in unusually high (outbreak) density in Jack Pine plantations in North-Central Ontario, 2) note what species may relate to the current outbreak of Jack Pine Budworm, and 3) compare the numbers of birds, mammals, amphibia, and arthropods of shrubs, herbs, and forest floor with and without spraying with **B.t.**20 (Thuricide 48LV, 20 B.I.U./ha delivered at 1.8 1/ha), **B.t.**30 (Futura XLV, 30 B.I.U./ha delivered neat, Matacil 180F (70g ai/ha delivered at 1.5 1/ha), and Fenitrothion (Sumithion F 20, 210g ai/ha delivered at 1.5 1/ha).

This is a preliminary report of ongoing work and more data and analyses are needed before firm conclusions and recommendations can be made.

Methods

Since 1979, some of us have censused birds, and noted mammals, amphibia, and arthropods in Jack Pine and Black Spruce forests throughout North-Central Ontario in an area bounded roughly by the settlements of Chapleau, Sudbury, and Kirkland Lake (James 1979, Szuba and Bendell 1983).

In 1981, we began and have continued detailed studies of birds, mammals, amphibia, and arthropods in plantations of Jack Pine along Highway 560 between Highways 144 and 560A (the exit to Westree). Among the forests and populations we study are two 20 year old plantations of Jack Pine called Gogama VA and VB, and a 40 year old stand coded as Gogama G. All are 100 ha or larger in size and are described in more detail in Naylor *et al.* 1985, Naylor and Bendell 1983, Spires and Bendell 1983, and Szuba and Bendell 1983.

In 1985, because of the outbreak of the Jack Pine Budworm, the O.M.N.R. sprayed the 20 year old forest (G-VA) with **B.t.** 20 and left a nearby forest (G-VB) as an unsprayed control. The Canadian Forest Service sprayed separate 50 ha blocks of the 40 year old forest with **B.t.** 30, Matacil, and Fenitrothion, leaving a large unsprayed portion which we used as a check area. The **B.t.** was sprayed once, each chemical twice, all from June 21 to June 27. From May through August we censused the birds, mammals, amphibia, and anthropods of shrubs, herbs, and forest floor to measure the effect of each kind and concentration of insecticide. Animals were counted in sprayed and unsprayed forests of the same age. All, except birds,

were counted daily. Birds were censused daily in late May and early June, immediately before and after each spray in June, and a week after the last spray.

Methods of Census

Songbirds were counted in late May and early June using transect counts as described by Emlen (1977), beginning at 0630 h. Before and after spraying, songbirds were censused beginning at dawn and walking at least one km of transect line, stopping for three minutes at 100m intervals, and noting the numbers heard singing and their location. Spruce Grouse were censused by searching with trained pointing dogs as described by Szuba and Bendell (1983). Varying Hare were counted along roads (Spires and Bendell 1983) and by tracks in snow crossing transect lines in forests. Small mammals, amphibia, and arthropods were enumerated on 2.3 ha plots with one plot in each spray treatment, and one unsprayed control plot each in young and old forest.

The small mammal plots measured 100m x 225m, with five lines spaced 25m apart down the greatest length of the plot. Trapping stations were placed at 25m intervals along each line for a total of 50 stations. Plots were placed 100m from the edge of a forest. Each trapping station consisted of a pitfall trap (16cm wide x 12cm deep, one-third filled with 30 per cent ethyl alcohol) and three mouse snap traps baited with peanut butter and oatmeal. At times, Longworth live traps replaced snap traps. The pitfalls captured small mammals, amphibia, and arthropods. Arthropods were also sampled by sweep netting along and between plot lines with approximately 700 sweeps a line directed at the shrubs and herbs. Small mammals were also sampled throughout the summer with lines of snap traps (25 stations, 25m spacing, three traps/station) in all plots, and grids of Longworth live traps (four grids, 40 stations/grid, 25 m spacing, three traps/station) in plots in the 40 year old Jack Pine.

Results

Abundance of Birds

Birds in unusually high numbers in the Jack Pine forests are presented in Table 1. Note that some birds were abundant before the outbreak of budworm; e.g. Spruce Grouse were four times the density recorded elsewhere. Quite spectacular increases in some birds occurred in the budworm year. Bay-breasted and Blackburnian Warblers increased more than 100 fold and also were in exceptionally high numbers compared to studies in boreal pine forests elsewhere. The greatest numbers of warblers were in the 40 year old forest where damage by, and presumably the abundance of, budworm was greatest (J. F. Bendell, Personal Observation).

In the budworm year, three species were epidemic in 20 year old pine, and five species were extremely abundant in 40 year old forest. Species that likely responded to and may function in the control of Jack Pine Budworm are the White-throated Sparrow and the warblers: Nashville, Bay-breasted, Blackburnian, Yellow-rumped, and Ovenbird.

Abundance of Mammals

Mammals in unusual abundance in the two Jack Pine forests are presented in Table 2. As with birds, some species were abundant before the outbreak of the budworm. The Masked Shrew occurred in unusually high density in the 40 year old forest in 1985 compared to other years and elsewhere. Moreover, the number of embryos per female was greater than reports in the literature. This insectivore may have responded to, and functioned in the control of the budworm.

Effect of the Insecticides on Birds

We detected no differences in the density of birds before and after spraying and between sprayed and unsprayed forests (Christie 1986).

Effect of the Insecticides on Small Mammals and Amphibia

The change in numbers of small mammals from one week before spraying to three weeks after was comparable in all spray and control areas (Table 3). Included was the Masked Shrew where relatively large numbers were sampled. Among the amphibia, numbers of the Wood Frog were apparently decreased by all the insecticides except Matacili (Table 4). The results indicate no detectable effect of the pesticides on small mammals and amphibia other than the Wood Frog over the period censused.

Effect of the Insecticides on Insects and Spiders of Shrubs, Herbs, and Forest Floor

A summary of the results is presented in Table 4. The numerical data are in Appendix A. Differences between numbers on sprayed and control plots were decided by no overlap of 2 x S.E. of mean N/100 sweeps. We censused eight groups of arthropods. From preliminary analysis, the number of groups apparently reduced by each insecticide was: Fenitrothion, four; **B.t.** 30, two; **B.t.** 20, one, and Matacil none. As expected, **B.t.** killed larval Lepidoptera almost exclusively.

Discussion

Our main findings are: 1) plantations of Jack Pine may contain outbreak densities of Spruce Grouse, Varying Hare, and Heather Vole, 2) the Masked Shrew, White-throated Sparrow and five species of warbler, notably the Bay-breasted and Blackburnian, increased spectacularly with, and likely responded to, the outbreak of the Jack Pine Budworm, 3) the insecticides had no immediate detectable impact on birds, small mammals, and amphibia other than the Wood Frog, and 4) among the eight groups of arthropods censused from shrubs, herbs, and forest floor, Fenitrothion depressed four; **B.t.** 30, two; **B.t.** 20, one; and Matacil none.

Plantations of Jack Pine produce exceptional densities of a few species of animals compared to their densities in other habitats elsewhere. Plantations of Jack Pine are monocultures in that the vegetation is essentially of the same species, age, and spacing. Monocultures may cause outbreaks of some animals including pest species (Cromartie 1981, Teetes 1981). Thus, the current outbreak of Jack Pine Budworm may be caused by the present monoculture plantations. We need to understand how monoculture plantations cause outbreaks of some animals. This knowledge may provide an alternative to insecticide control of outbreaks by showing how to prevent outbreaks before they start. Perhaps different methods of silviculture could be used to obtain desired densities of animals. We have discussed how the resources required by animals may be distributed in monoculture plantations to cause high density (Naylor *et al.* 1985, Zwickel and Bendell 1985). More money is needed to solve the problem of the relationship between monocultures and outbreaks. This crucial research would cost but a small fraction of what is spent on pest control by spraying from aircraft.

A number of birds and one species of mammal became extremely abundant in the forests in the year of the budworm outbreak. This effect has been noted during outbreaks of the Spruce Budworm in mixedwood forest (Welsh 1983). Considering the species on the basis of their food habits, habitat requirements, and the magnitude of their numerical increase with the budworm, those most likely important as predators of the budworm are the Bay-breasted and Blackburnian warblers. The White-throated Sparrow, and three other warblers also increased numerically and should be regarded as other predators. More research is needed to measure the functional and numerical responses of bird and mammal predators and how these responses may be manipulated to improve budworm control.

Currently, we have not detected an effect of the insecticides on birds, small mammals, and amphibia other than the Wood Frog. However, there may be a delayed response and numbers should be measured on the sprayed and unsprayed plots in 1986. Lepidopteran larvae and beetles are important foods of some wildlife and their reduction may cause a decrease in the numbers of animals that feed on them. The large number of Wood Frogs captured on the control plot in old forest is surprising; moreover, it also weakens the validity of the area as a control.

In terms of apparent impact on non-target arthropods, Matacil was the least harmful spray, and Fenitrothion the most harmful. However, all sprays but Matacil killed larvae of Lepidoptera in the forest understory.

The decrease in wasps may relate to the increased concentration of **B.t.** and the decrease of arthropod hosts to parasitic wasps. The **B.t.** had a comparable effect in young and old forests.

The no effect of Matacil may mean it did not reach the ground. We are analyzing droplet detection plates to measure the deposition of the insecticides.

We stress the preliminary nature of our analysis and results. Birds, mammals, amphibia, and arthropods vary in density yearly, locally, and within a year. Some animals are in sparse abundance naturally. Thus, differences in density caused by insecticide application are difficult to detect. More powerful statistical analysis may improve our accuracy. Some of our sampling must be done on larger and more representative areas and with more samples and replicates if we are to obtain accurate estimates of density. We also need more data on the abundance of species in natural stands of Jack Pine and where they occur elsewhere.

The differences we detected in the density of arthropod groups in sprayed and unsprayed plots may have little ecological effect. We used the census of the week before spray and the week after to measure effect. Two to three weeks after spraying, some invertebrate groups had recovered and their densities matched those on control plots. On the other hand, some groups were apparently knocked down in the two weeks after spray, and some did not recover.

The capture of arthropods in pitfall traps is presently under examination. This method of sampling will give an improved picture of the ground and litter dwelling insects and spiders of the forest floor.

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Table 1. Species of birds in high density in plantations of Jack Pine.

Year	20 yr old forest	40 yr old forest
1981, 1982	Spruce Grouse[a] Nashville Warbler[b]	
1983	Spruce Grouse	
1984	Spruce Grouse	
1985	Budworm Year	
	Spruce Grouse Nashville Warbler[c] White-throated Sparrow[d]	Bay-breasted Warbler[e] Blackburnian Warbler[f] Yellow-rumped Warbler[g] Ovenbird[h] Nashville Warbler[i]

(a) 1981-1985, Szuba and Bendell (1983) and ongoing, 50/100 ha vs 19/100 ha, the highest density in four studies elsewhere.

(b) 1981, J. F. Bendell (Personal Observation); 1982, J. F. Bendell (Personal Observation, S. Nash and A. Nash, Personal Communication).

(c-i) James (ongoing, six km of line) compared to the highest density/100 ha in four studies elsewhere in Jack Pine forest (Erskine 1977, McLeod 1967, 1974, Ralph 1980), (c) 61 vs 7, (d) 47 vs 18, (e) 153 vs 15, (f) 94 vs rare, (g) 63 vs 29, (h) 61 vs 2, and (i) 44 vs 7.

Table 2. Species of mammals in high density in plantations of Jack Pine.

Year	20 yr old forest	40 yr old forest
1981	Varying Hare (a)	Heather Vole (c)
1982		Heather Vole (c)
1985	Budworm Year	
	Varying Hare (b)	Masked Shrew (d)

(a) An average of 20 pellets/m^2 quadrat, compared to an average of eight pellets/m^2 quadrat in a nearby mixed forest of the same age (Scarr 1985). Extremely abundant along roads as compared to elsewhere (J. F. Bendell, B. J. Naylor, and K. J. Szuba, Personal Observation; Spires and Bendell 1983).

(b) An average of 10 tracks/100m (N = 30) in 20 yr old forest to one track/100m (N = 30) in 40 yr old forest.

(c) 10/100 trap nights compared to 4/100 trap nights, the greatest density in 13 studies elsewhere (Naylor et al. 1985).

(d) 3/100 trap nights (N = 8200) compared to 1/100 trap nights, the greatest density in three studies elsewhere (Carter and Brown 1974, Martell 1984, Quimby 1943).

Table 3. Effect of the insecticides on small mammals

Mammals/100 pit nights[a]	Plots	B.t. 20[c] 20 yr old Jack Pine 1 week before spray	B.t. 20[c] 20 yr old Jack Pine 3 wks after spray	B.t. 30 1 week before spray	B.t. 30 3 wks after spray	Matacil 40 yr old Jack Pine 1 week before spray	Matacil 40 yr old Jack Pine 3 wks after spray	Fenitrothion 1 week before spray	Fenitrothion 3 wks after spray
Masked Shrew	Spray	6	4	4	2	3	2	3	2
	Control	5	3	4	3	4	3	4	3
Rodents[b]	Spray	0	0	1	1	1	1	0	0
	Control	1	0	0	0	0	0	0	0

(a) Each census is based on 350 pit nights.

(b) Mostly Deer Mouse and Least Chipmunk in 20 yr old Jack Pine, and Deer Mouse and Redback Vole in 40 yr old Jack Pine.

(c) Date of spraying: **B.t.** 20, June 27; **B.t.** 30, June 25; Matacil and Fenitrothion, June 21 and June 26.

Table 4. Effect of the insecticides on amphibia

Amphibians	Plots	B.t. 20 20 yr old Jack Pine 3 wks[a] before spray	B.t. 20 20 yr old Jack Pine 4 wks after spray	B.t. 30 3 wks before spray	B.t. 30 4 wks after spray	Matacil 40 yr old Jack Pine 3 wks before spray	Matacil 40 yr old Jack Pine 4 wks after spray	Fenitrothion 3 wks before spray	Fenitrothion 4 wks after spray
American Toad	Spray	0	2	1	6	1	20	0	9
	Control	1	11	0	10	0	10	0	10
Wood Frog	Spray	1	0	5	22	4	82	5	6
	Control	0	13	5	431	5	431	5	431
Other[b]	Spray	4	1	2	4	1	2	1	3
	Control	1	0	0	2	0	2	0	2

(a) Each week represents 350 pit nights; 1050 pit nights before spray and 1400 after.

(b) Other amphibians captured in numbers <5 were: Gray Treefrog, Blue-spotted Salamander, Yellow-spotted Salamander, and Redback Salamander.

Table 5. Effect of the insecticides on the numbers of insects and spiders of shrubs, herbs, and forest floor

Arthropod	B.t. 20 20 yr old Jack Pine	B.t. 30	Matacil 40 yr old Jack Pine	Fenitrothion
Lepidoptera (larvae)	— (depressed)	—	0 (no effect)	—
Ants	0	0	0	0
Beetles (adult)	0	0	0	—
Grasshoppers	0	0	0	0
Flies	0	0	0	—
Bugs	0	0	0	0
Wasps	0	—	0	—
Spiders	0	0	0	0

Appendix A. Counts of arthropods before and after spraying with insecticides

Average no. of arthropods /100 sweeps (N sweeps)	± SE Plots	B.t. 20 20 yr old Jack Pine Wk[a] before	B.t. 20 20 yr old Jack Pine Wk after	B.t. 30 Wk before	B.t. 30 Wk after	Matacil 40 yr old Jack Pine Wk before	Matacil 40 yr old Jack Pine Wk after	Fenitrothion Wk before	Fenitrothion Wk after
Lepidoptera (larvae)	Spray	8.5 ± 1.65 (2702)	1.5 ± 0.20 (3240)	8.9 ± 1.17 (3496)	4.0 ± 0.80 (3592)	6.2 ± 0.84 (3649)	4.6 ± 0.24 (3486)	8.6 ± 1.10 (3280)	5.5 ± 1.78 (3482)
	Control	6.5 ± 1.00 (2977)	4.5 ± 0.60 (3391)	4.8 ± 0.60 (3354)	4.9 ± 0.80 (3539)	4.7 ± 0.60 (3354)	3.4 ± 0.41 (3539)	4.7 ± 0.60 (3354)	3.4 ± 0.41 (3539)
Ants	Spray	2.3 ± 0.30	0.8 ± 0.28	1.5 ± 0.42	1.6 ± 0.19	1.0 ± 0.18	0.9 ± 0.27	0.9 ± 0.10	0.4 ± 0.09
	Control	1.8 ± 0.32	1.3 ± 0.18	0.6 ± 0.20	1.3 ± 0.48	0.7 ± 0.28	1.4 ± 0.48	0.7 ± 0.28	1.4 ± 0.48
Beetles	Spray	6.5 ± 1.50	2.0 ± 0.10	8.5 ± 2.30	4.0 ± 0.84	19.0 ± 3.60	8.0 ± 1.37	14.0 ± 1.10	0.3 ± 0.08
	Control	10.5 ± 0.50	6.0 ± 0.50	5.0 ± 1.10	4.0 ± 0.76	5.5 ± 1.13	4.1 ± 0.76	5.5 ± 1.13	4.1 ± 0.76
Grasshoppers	Spray	5.5 ± 1.50	4.5 ± 0.31	0.15 ± 0.11	0.23 ± 0.06	0.62 ± 0.20	0.87 ± 0.29	0.03 ± 0.00	0.04 ± 0.04
	Control	5.5 ± 0.12	3.1 ± 0.27	0.03 ± 0.00	0.11 ± 0.05	0.01 ± 0.00	0.10 ± 0.05	0.01 ± 0.00	0.10 ± 0.05
Flies	Spray	4.0 ± 1.20	9.1 ± 2.00	5.5 ± 1.64	8.5 ± 1.00	4.2 ± 0.55	8.0 ± 0.92	4.5 ± 0.37	5.0 ± 0.62
	Control	2.2 ± 0.40	8.0 ± 1.80	4.5 ± 0.66	10.0 ± 1.52	4.6 ± 0.46	10.3 ± 1.51	4.6 ± 0.46	10.3 ± 1.51
Bugs	Spray	0.1 ± 0.01	1.1 ± 0.34	1.7 ± 0.74	2.0 ± 0.20	1.6 ± 0.16	2.3 ± 0.32	2.4 ± 0.49	0.8 ± 0.16
	Control	0.6 ± 0.44	2.6 ± 0.60	1.1 ± 0.26	1.4 ± 0.48	1.5 ± 0.54	1.5 ± 0.45	1.5 ± 0.54	1.5 ± 0.45
Wasps	Spray	2.3 ± 0.60	1.5 ± 0.52	0.7 ± 0.23	1.5 ± 0.32	1.0 ± 0.18	1.5 ± 0.15	1.0 ± 0.15	0.5 ± 0.17
	Control	0.8 ± 0.30	2.2 ± 0.22	0.7 ± 0.35	2.3 ± 0.60	0.7 ± 0.30	2.5 ± 0.64	0.7 ± 0.30	2.5 ± 0.64
Spiders	Spray	1.2 ± 0.24	0.8 ± 0.08	2.7 ± 0.59	3.2 ± 0.45	1.6 ± 0.48	0.9 ± 0.21	2.3 ± 0.44	1.1 ± 0.21
	Control	1.3 ± 0.23	1.1 ± 0.20	1.7 ± 0.37	1.8 ± 0.33	2.4 ± 0.36	1.9 ± 0.34	2.4 ± 0.36	1.9 ± 0.34

*(a) For **B.t.** 20, week before was June 20, week after July 4, **B.t.** 30 June 18 and July 2, Fenitrothion and Matacil June 14 and July 3 because the 2 chemicals were sprayed twice; both on June 21 and June 26.*

The Sex Pheromone of the Jack Pine Budworm (*Choristoneura pinus pinus*)[1]: Identification of Pheromone Components and the Development of a Monitoring System

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Preliminary studies have shown that the chemical identity of the major (primary) sex pheromone components of jack pine budworm, ***Choristoneura pinus pinus****, Freeman, are a blend of 85:15(E/Z)-11-tetradecenyl acetates and 85:15(E/Z)-11)tetradecen-1-ols (in a 9:1 Ac:OH ratio). Activity was determined by EAG assays and field trapping experiments. A 0.1% (w/w) PVC source containing these chemicals captured similar numbers of males in sticky traps as did virgin female-baited traps. Preliminary wind-tunnel studies indicated, however, that this blend effective as a trap bait, is not equivalent to females in eliciting male responses. In order to develop a reliable pheromone monitoring system for this insect, an appropriate trap bait needs to be developed. This includes identifying the complete pheromone blend and formulating a suitable controlled-release source that maintains release integrity of this blend over the entire trapping period. Variability in trap capture due to the trap-bait will then be minimized and a monitoring scheme can be developed.*

Introduction

Pheromone components for most of the known coniferophagous budworms have been documented (reviewed in Silk and Kuenen, 1982, 1986). Only in the case of the spruce budworm, **Choristoneura fumiferana** (Clemens) has some progress been made in developing a pheromone monitoring system (Allen *et al.*, 1986).

The jack pine budworm (JPBW), **Choristoneura pinus pinus**, can be a serious defoliator on **Pinus** spp. notably **P. banksiana** and **P. resinosa** (Freeman and Stehr, 1967). JPBW is sympatric with the spruce budworm, **C. fumiferana**, for part of its range in the Acadian, Great Lakes-St. Lawrence and Boreal forest types (Freeman, 1953; Stehr, 1967).

Infestations and damaging densities of this insect appear quickly and can last several years (Applejohn and House, 1983). A pheromone trapping system which could potentially warn of population increases, would be extremely useful. To this end, we began several years ago to develop a monitoring system using the female sex pheromone. We identified pheromone components (Silk *et al.*, 1985) and conducted field trapping studies, both in New Brunswick and Ontario, and more recently we cooperated in field studies with workers in Manitoba.

Methods and Results

Methods used to isolate and identify pheromone components of **C. pinus pinus** have been detailed elsewhere (Silk *et al.*, 1985). Chemical, electrophysiological and trapping experiments were conducted. EAG responses are shown in Figure 1; field trapping results from New Brunswick and Ontario are presented in Figure 2 and Figure 3, respectively.

Both the acetate and alcohol components were detected in chemical analyses of JPBW pheromone gland extracts and gland effluvia; however, "conventional" Porapak Q effluvial ratios were greatly skewed apparently due to autodegradation of the acetate to the alcohol (Silk *et al.*, 1985). EAG studies (Fig. 1) indicated the importance of the *E*/*Z*11-14:Ac as a pheromone component but the *E*/*Z*11-14:OH was not strongly EAG active. Trapping studies (Figs. 2 and 3), however, pointed to the importance of both acetate and alcohols for producing trap capture.

These effects were predicated on preliminary be-

1. Lepidoptera:Tortricidae.

havioral experiments in our sustained-flight wind tunnel where we found that males were activated (wing fanning initiated) by the *E/Z*11-14:Ac but flight was not initiated. Addition of the OH's to the AC's resulted in both activation and flight initiation, with some males flying upwind toward the chemical source (none reached the source). When an everted female's sex pheromone gland was placed at the upwind end of the tunnel, all males that were tested flew upwind and reached the gland.

Clearly, both the Ac's and OH's are necessary to effect trap capture, yet this combination is not near the natural pheromone as indicated by our wind tunnel studies. This lack of definition of the complete female sex pheromone blend may be an important contributor to the variability in trap capture. By inference, therefore, the elucidation and use for trapping of the complete sex pheromone blend should reduce trap capture variability and allow for a greater potential of the development of a pheromone-trap based monitoring system for the jack pine budworm.

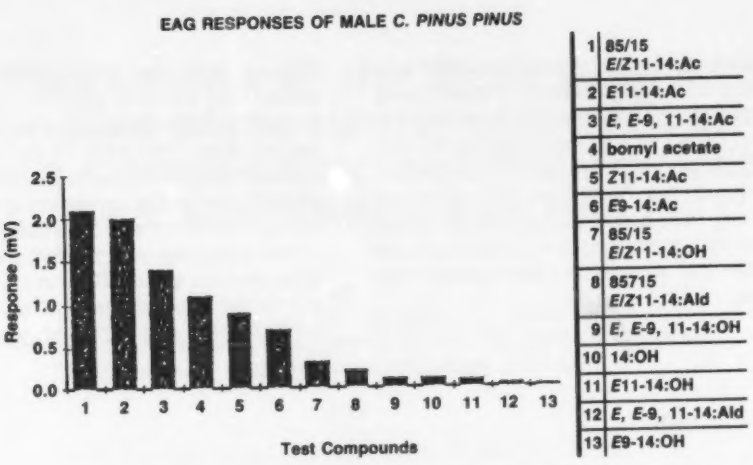

Figure 1

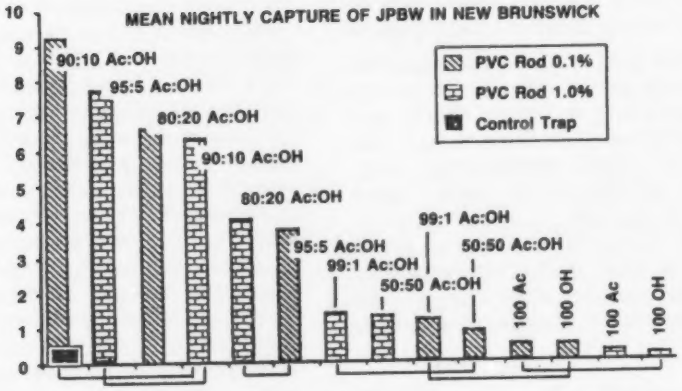

Figure 2

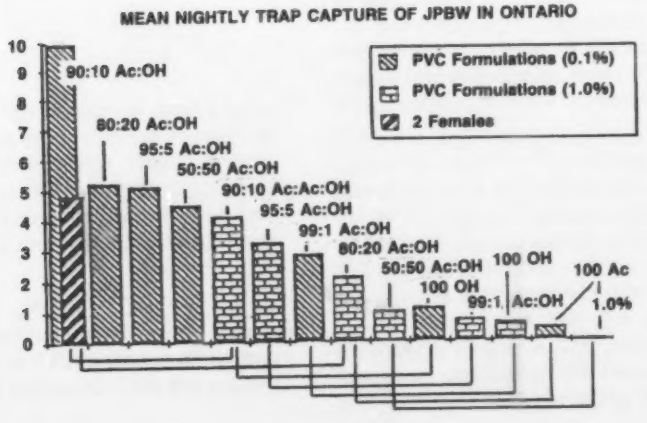

Figure 3

Monitoring Jack Pine Budworm Using Pheromone Traps

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Jack pine in the Maritimes is a species of lesser importance, probably ranking sixth behind the spruces, fir and white pine, however, where it does grow it is indeed an important species and the subject of reforestation programmes. In New Brunswick it represents about two per cent of the commercial wood volume, however, 50 per cent of the seedlings that are planted are jack pine.

The Jack pine budworm (JPB), in non-outbreak years, receives only minor attention so that when an outbreak threat does occur we must scramble to catch-up on our monitoring of the status of the pest.

As a survey group we normally assess populations of insect pests using time honored methods of larval assessment, egg counts and etc. Recently we have been looking to pheromones to relieve some of the burden of this work and to enhance the predictive aspects of pest monitoring. The jack pine budworm is one of eight pests for which we have been working on pheromone monitoring systems in the Maritimes. The Jack pine budworm pheromone trapping has been done in cooperation with the New Brunswick Department of Forests, Mines & Energy.

There are various monitoring possibilities, depending upon the degree of information which is desired and the amount of effort available to be spent on them. One can trap for 1. **Detection** (whether or not the insect is found in the area); 2. **Early Warning** of population build-up (using indications of population size and fluctuations) or 3. **Damage Prediction/Measurement** where one estimates population size well enough to predict a level of damage.

Much of our work has concentrated on the first two — Detection and Early Warning. Our aim is to develop an early warning threshold of trap capture which will cue us to a build-up of insect populations to the point where a significant level of host damage is imminent. Once this threshold is reached, more detailed (time consuming and expensive) larval and defoliation surveys can then be planned for targeted areas the following season. Such detailed surveys are often hard to justify in non-outbreak years, and because of the 'hit and miss' nature of monitoring endemic populations they often give insufficient warning of impending outbreaks. It is important to develop correlations of trap catch with numbers of the pest on the trees, even for simple uses of pheromone trapping, however the precision required is much less than would be needed for predictions of the amount of defoliation which might occur.

Our emphasis to date has been the establishment of a base-line trap catch to be compared with the catch in succeeding years, and to determine that threshold level. To many of you who are currently experiencing a JPB outbreak this early warning threshold work will have to wait until the next time around. Certainly an attempt to correlate trap catch with level of defoliation is an exercise which someone must try — I'll admit that the main reason that we haven't done this as yet in the Maritimes is that our populations during the last few years have been trace to low throughout the region!

Our work to date then has been to take the Research and Productivity Council lure, "as is"[1] to put this lure into an inexpensive trap (outbreak populations might require a non-saturating type of trap), and place a large number of these traps throughout the areas of jack pine in the province. This we did in 1984 using the small Pherocon II trap. Further, to keep the program simple enough to meet our operational requirements we put the trap out early, one to three weeks before we expected the first moth to fly, we did not check or replace traps during the season, and we picked them up late, two to four weeks after the last moth was expected to have flown. We also tested three concentrations of lure, but found such small, non-statistically significant differences that we lumped all of our data.

[1] (further refinement may be possible but as long as it can attract at a consistent rate, it should work at endemic or low population levels; trapping over a wider range of population densities may require a lure which is better able to compete with a high density of JPB females)

We have a good idea of the distribution of jack pine in New Brunswick where the majority of jack pine in the Maritimes is to be found, from the N.B. forest inventory. In the map, each grid, representing about 10,000 ha, is coded according to the area of all stands within, which have jP as one of the predominant species. This inventory was used as a guide to placing our traps and can be of help in interpreting the results.

We were generally pleased with our 1984 results (Figure 1):

1. We caught an average of about six moths per trap, excluding negative traps. We could have come up with nothing if the lure concentration, trap type, weather or budworm populations were off, or we could have had fully saturated traps giving little relative information.
2. The range of numbers caught and their distribution suggest that this was a rather sensitive index to differing population levels. Indeed we caught no moths where jack pine was an uncommon species. This is important as it suggests that in-blown moths, at least at our low regional population densities, were not an important factor. Our highest catches were in that part of New Brunswick where the preceding year we had detected some jack pine budworm defoliation, although this defoliation was not much. In-between numbers were caught where jack pine inventories were high but little defoliation was encountered in 1983. I think that it is important to keep in mind that there were no nearby outbreaks of JPB and significant defoliation was not detected during this trapping period — a truly 'simple' situation.

One observation that we had is that, if these numbers can be trusted (that is we have just started to see what correlations to larval numbers or some standard exist), then this map may be the best description of relative JPB numbers in the Maritimes which we have ever obtained. This may have told us, for relatively little money, what a couple of experienced crews might have labored weeks to describe or it may have some predictive value to replace egg surveys or overwintering larvae surveys which are not nearly as accurate as we would like them to be.

In 1985, we repeated this work using one lure concentration. We found that, overall, the trap catch had doubled (Figure 2). Further, the highest numbers were not localized in one area of the province, but were up in most areas where jack pine was an important forest species. Peak numbers were not much different than in 1984, although we may be seeing the first effects of trap saturation in this. For 1984 we have almost no larval sampling data — our routine larval surveys drew negative results and in our first year of this work we could not afford an extensive survey to quantify these 'negatives'. From this season we do have better population information which shows trace to low levels of budworm especially in areas where there was a good flowering crop[2]. The point is that our trap catch doubled from 1984 to 1985 and our observations hint that this may be related to a slight increase in larval populations on the branch. We may be approaching our Early Warning Threshold. I am concerned that trap saturation may occur, given our choice of trap, before the EWT is reached.

We have some evidence now of the predictive ability of jack pine budworm pheromone trapping. For seven locations, widely separated in New Brunswick, we correlated mean trap catch for 1984 with number of mature JPB larvae in 1985, obtaining an $r = 0.60$ (Figure 3). We also calculated a correlation coefficient for 1985 trap catch with number of larvae in 1985 and came up with a low $r = 0.36$, and for 1984 trap catch with 1985 trap catch yielding an even lower $r = 0.14$.

This past year we also had three test areas where three lure concentrations were tested with controls in a randomized complete block design. Each block contained two of each test concentration and three controls and was replicated four times per location. My initial look at the data reveals rather higher than desired (but probably good by most pheromone trapping standards) coefficients of variation of from 54 per cent to 88 per cent, indicating that either we will require fairly high sample sizes or that possibly some work can be done on the sampling system (trap design, lure blend, etc.).

Our choice of lure concentrations, 0.0003 per cent, 0.003 per cent, 0.03 per cent, yielded a better contrast in trap capture than in 1984 when higher concentrations were used, but we have not done any statistical work on the numbers as yet (Table 1).

Table 1. Mean trap catch for three concentrations of jack pine budworm pheromone lure at three New Brunswick locations.

Location	Lure Concentration			
	Control	0.0003	0.003	0.03
Cains R.	0.55	2.75	10.63	25.75
Despres L.	0.18	0.63	1.63	24.00
Eskedelloc R.	0.40	0.29	0.75	17.38

We shall maintain this monitoring effort for the next several years, working towards the early warning

[2](Incidence of flowering caused a serious sampling problem. That is, the pest was distributed in the trees relative to the intensity of flowering. Does one sample a tree with no flowers, a few, many? This can affect ones choice of branch, tree, side of the road or county. One estimate we are trying is counting the number of flower clusters on each branch and using a budworm/flower cluster index)

threshold and time series data to better describe population fluctuations. When reached it will then demand another type of sampling intensity or possibly an altered programme of pheromone trapping to relate trap catch to level of defoliation.

There is certainly some distance to go with this work. Part of the reason that I have not presented a fuller analysis of these data is that the condition of the moths in some traps is so poor (the trap having been left out so long) that we must recheck them all under the microscope for a positive identification. Fortunately few moths of other species stumble into the traps.

We also have measurements of stand-species composition and density which I feel will be an important covariate to trap captures.

A final caution. Our increase in catch from 1984-85 might not be due to an increase in JPB but; 1. to an overall 'good' year for trapping, whether caused by cloud cover, temperature or other unknown variables, 2. variations in lure production lots from year to year, 3. minor modifications are made to the Pherocon II trap for 1985, or possibly some other undetermined factors.

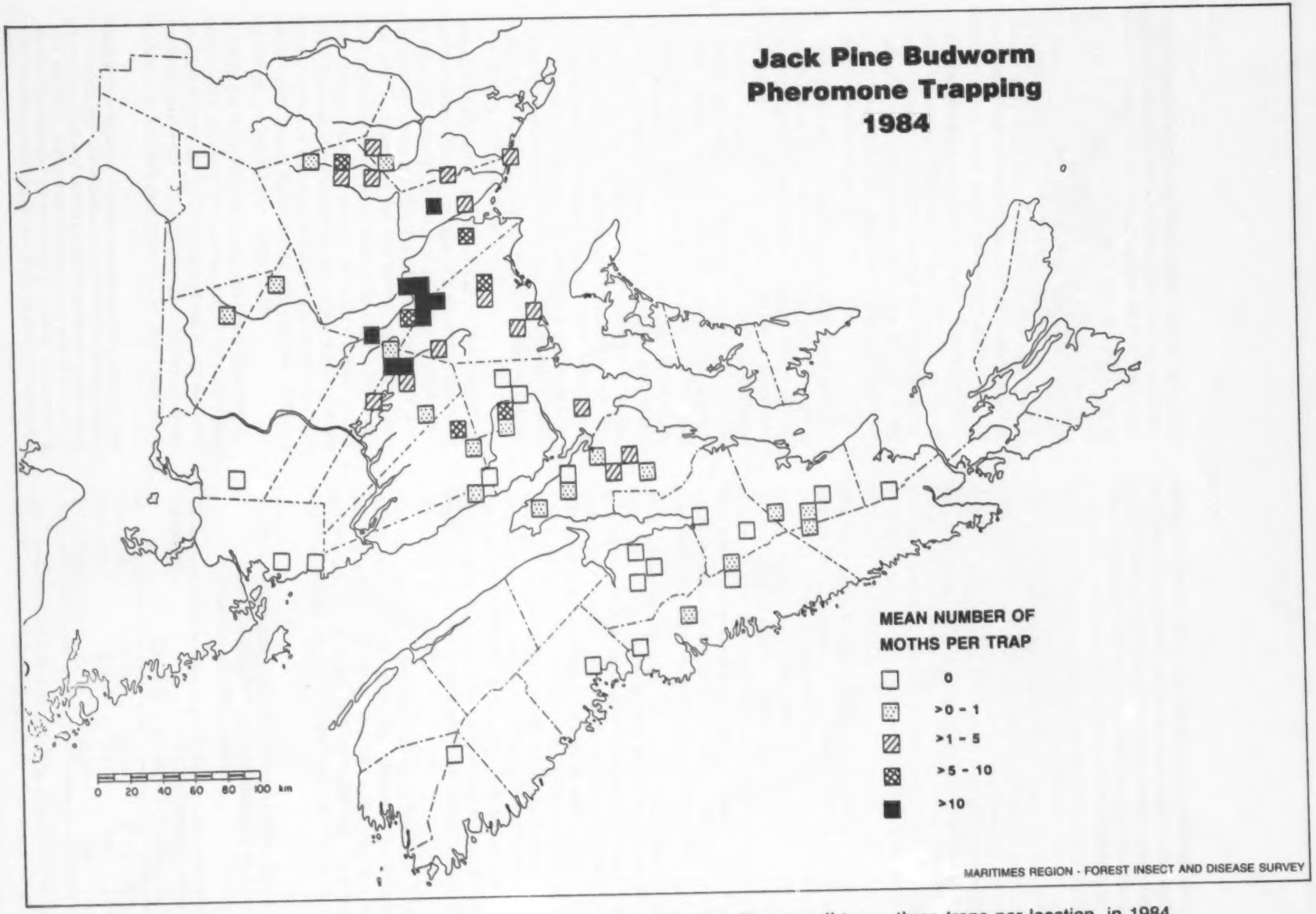

Figure 1. Results of jack pine budworm pheromone trapping using Pherocon II traps, three traps per location, in 1984.

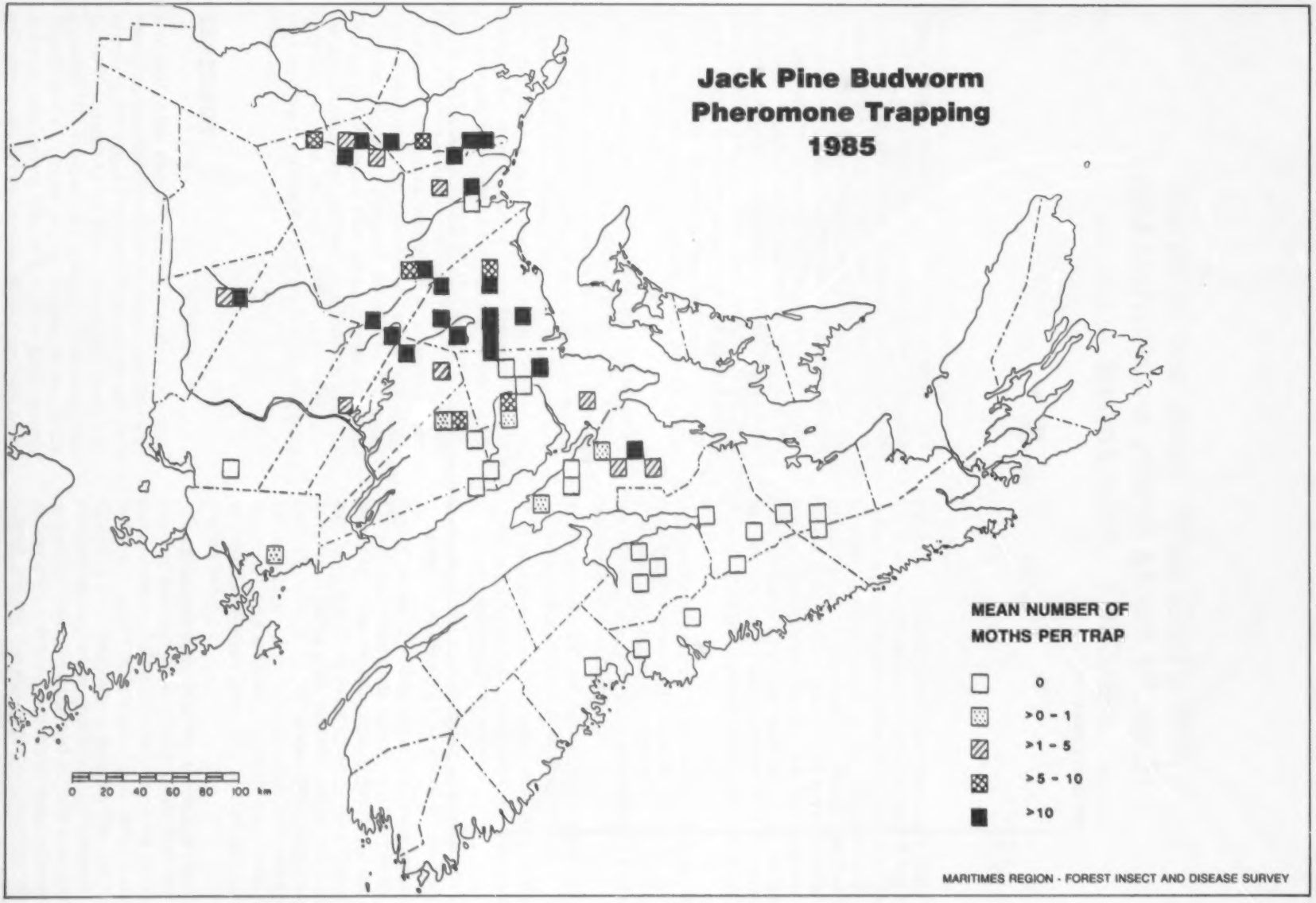

Figure 2. Results of jack pine budworm pheromone trapping using Pherocon II traps, two per location, in 1985.

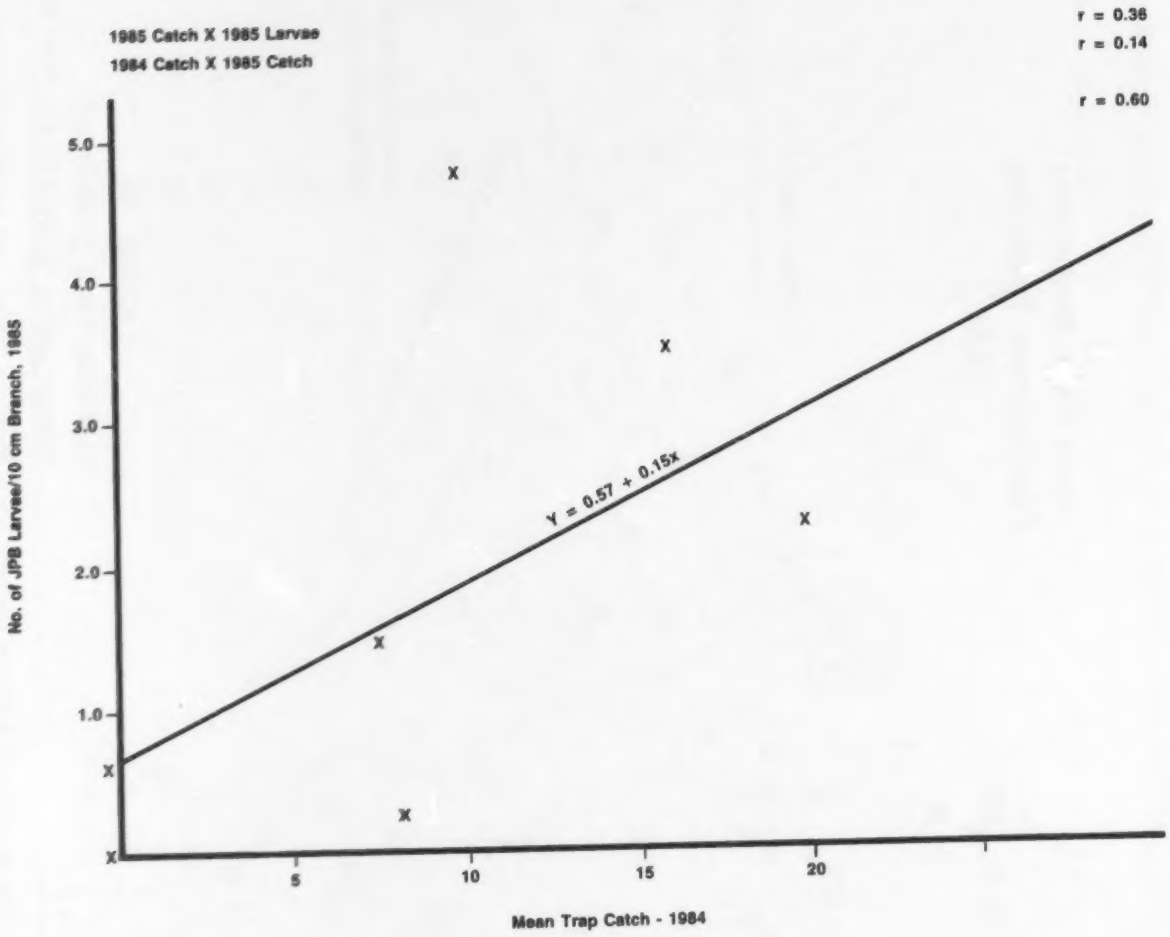

Figure 3. Correlation of mean trap catch 1984 with numbers of jack pine budworm larvae 1985 (r = 0.60, ns).

Surveys for Jack Pine Budworm (*Choristoneura pinus pinus* (Free.)) in New Brunswick, 1983/84

by
D. R. Lavigne and N. E. Carter

*Forestry plays an important role in the economy of all regions of New Brunswick, as indicated by the fact that in 33 of 67 single-industry communities, forestry represents the only industry (Watson, 1983). Approximately 85 per cent of the area of the Province is productive forest land of which 65 per cent is softwood species. The major softwood trees are balsam fir and the spruces (black, red and white) (Anon., 1981). The age class structure of the softwood forest and the presence of eastern spruce budworm (**Choristoneura fumiferana** (Clem.)) have created perennial forest protection and forest management problems (Baskerville, 1983) within the Province as exemplified by the controversial annual spray program dating back to 1952 (Irving and Webb, 1985).*

Jack pine, however, is not a significant species within the natural forests of New Brunswick. In fact, provincial inventory statistics estimate jack pine to account for only 2.5 per cent of the existing softwood volume (Anon., 1981). Nevertheless, since the mid-1960s jack pine has been a very important component of the reforestation effort on Crown land within the Province. For example, up to 1983 it represented 44 per cent of all the Crown land planting effort. Therefore, in 1983 when the annual aerial defoliation survey detected moderate and severe defoliation in plantations and natural stands of jack pine in the central part of the Province (Figure 1) (Magasi, 1984), the Provincial Department of Natural Resources decided to survey the area to determine whether direct control might be necessary in 1984. This report briefly outlines the surveys that were conducted and the results that were obtained.

Methods

A review of the literature and discussions with entomologists in other Provinces revealed that little was known in 1983 about making forecasts of jack pine budworm except for an egg mass survey developed in Ontario (G. Howse, pers. comm.). This survey was based on the number of egg masses on six 60-cm (24-inch) mid-crown branch tips from each sample point from which the forecast infestation level could be determined by referring to the categories shown in Table 1.

Because the decision to survey was made late in the fall, it was not practical to conduct a reliable egg mass survey. Instead, it was decided to try a survey for overwintering second instar larvae (L2) similar to that which had been developed for the spruce budworm (Dorais and Kettela, 1982). Trials were subsequently conducted and revealed that the overwintering jack pine budworm L2 larvae could be extracted using a hot one per cent NaOH solution, two-hour soaking time with frequent agitation (15-20 min.), and a double rinse.

In order for this survey to be useful, however, it was necessary to develop an L2 table that could provide infestation categories for making the forecast. Using the following assumptions, a **provisional** L2 forecast table was derived (Table 2):

1. It was assumed that each egg mass had approximately 40 eggs/mass (DeBoo and Hildahl, 1968).
2. It was assumed that upon emergence from the eggs the larvae dispersed over the whole branch to seek overwintering sites.
3. It was assumed that dispersal loss and overwintering mortality would be about 50 per cent.

It must be stressed that this was a **provisional** table to meet our immediate needs and its validity was **unknown**. Nevertheless, having developed the forecast table, the L2 survey was conducted. Overall, 35 sample locations were selected within the infested area. Of this total, 23 points were from jack pine plantations about 10 to 15-years old and about three meters tall. The remaining 12 points were within natural immature/mature jack pine stands about seven meters tall.

At each sample point three representative trees were selected and one whole branch taken from the mid-crown of each. Before the branches were processed in the L2 'wash', each branch was divided into the 60-cm tip and remainder to examine the distribution of overwintering larvae. In addition, an estimate of the amount of flowering expected in 1984 was made by counting the number of immature male buds on each branch. Initially, this was done by dissecting individual buds, but after a few days, the observers began to

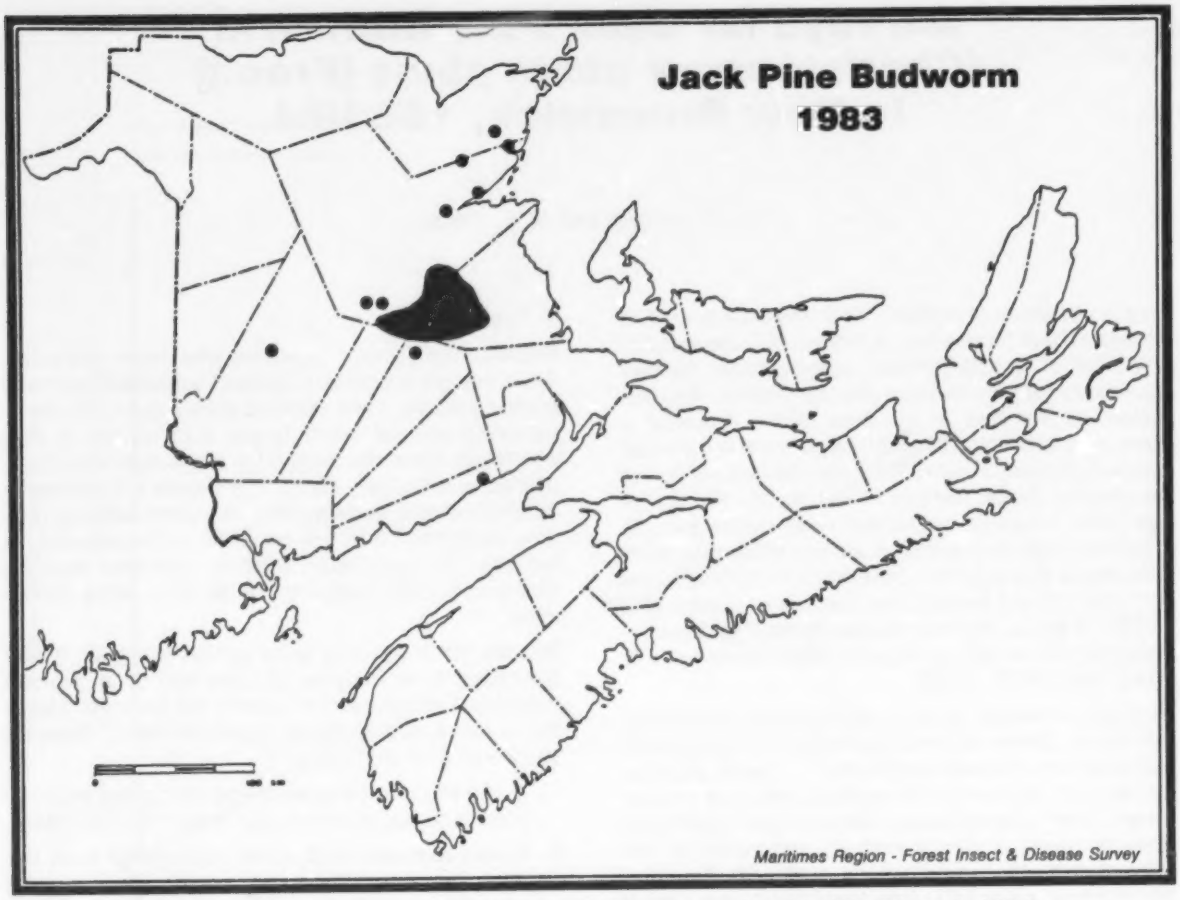

Figure 1. Defoliation caused by jack pine budworm in New Brunswick in 1983 (Magasi, 1984).

Table 1. Egg mass categories used to forecast jack pine budworm infestation levels in Ontario (G. Howse, pers. comm.).

Total no. egg masses on six 60-cm branch tips	Infestation Forecast
0	Nil
1-2	Light
3-5	Moderate
6+	Heavy

Table 2. Forecast infestation categories based on jack pine budworm egg masses and second instar (L2) larvae. (Refer to text for assumptions used to convert from egg mass to L2).

Total no. egg masses on six 60-cm branch tips	Total no. L2 larvae per whole branch	Infestation Forecast
0	0	Nil
1-2	1-9	Light
3-5	10-19	Moderate
6+	20+	Heavy

class the buds ocularly without dissection. It was felt necessary to estimate potential male flowering since previous studies (Lejeune and Black, 1950) indicated that increases in jack pine budworm populations appeared to be related to the abundance of male flowers.

To complete the investigation it was also decided that a subsequent survey (of the same trees) would be conducted in the summer (July) of 1984 to estimate the population of late instar larvae and the level of current year's defoliation that had occurred.

Results

1. L2 Forecast

When the L2 survey was completed, it was found that only four of the 35 sample locations had produced larval numbers great enough to fall within the LIGHT infestation class. The rest fell in the NIL infestation class. Based on these results, it was decided that direct control was not necessary for 1984. The July survey confirmed the forecast (see 4 below).

2. Distribution of Overwintering L2 Larvae

Having processed the L2 branch samples into the 60-cm tips and remainder, it was decided to examine the distribution of overwintering larvae (per 10-cm length) on these two components. Although there was no linear relationship (Figure 2), there was some indication that at this low population density more larvae were found on the basal portion of the branches than the 60-cm tips. It appears, therefore, that this relationship should be more fully examined before a standard L2 sample unit can be determined.

3. Relationship Between Overwintering L2 and Mature Larvae

The value of using numbers of overwintering L2 larvae to predict the numbers of late instar larvae was examined (Figure 3). The number of mature larvae encountered was lower than the number found in the L2 survey. One would expect this to be a reasonable observation as normal dispersal loss and natural mortality would contribute to the decline. No linear relationship was indicated when all points were considered ($r^2 = 0.10$), but when the three anomalous points with low numbers of L2 and high numbers of mature larvae were eliminated, the relationship improved ($r^2 = 0.33$). Further investigation is necessary to clarify the relationship, but there does appear to be merit in this type of forecasting system.

4. Defoliation Survey

Branch defoliation estimates made in July confirmed the low level of damage that was predicted using the numbers of L2 from the 'wash' and the forecast table that was developed. Most sampled areas (94 per cent) had defoliation less than 25 per cent. Although current defoliation was only rated in 25 per cent classes, only two areas were found with trees in the 26-50 per cent range. In future, it would appear more appropriate to classify defoliation in 10 per cent classes, though this procedure would not have enhanced this particular study because of the low larval numbers and light damage that was encountered.

5. Relationship Between Mature Larvae and Male Flowering

During the July survey, the number of male flower clusters were counted along with the number of mature larvae that were found. At the low larval density that was present, there was no linear correlation ($r^2 = 0.05$) between increases in the number of mature larvae and increases in male flower density (Figure 4). Although Lejeune and Black (1950) demonstrated that there was a general increase in larval density with increases in male flowers, the trend was not strong in one of six years' data they reported (i.e. the year with the lowest larval density). It may be, therefore, that densities of jack pine budworm larvae have to exceed a certain threshold before the presence of male flowers has any material influence on the subsequent increase in population levels. Presumably, the larval densities encountered in this study were below such a threshold. Conversely, however, it may have been that the level of male flowering that occurred in this situation was not sufficient to elicit the expected response.

6. Ability to Predict Male Flowering

Figures 5 illustrates the relationship between the number of immature male strobili estimated from the winter survey and the number of male flower clusters from the July survey. A weak linear relationship was indicated ($r^2 = 0.30$) with the regression line showing that the winter survey overestimated the actual levels of flowering that materialized. For explanation, it may be that not all buds were correctly categorized, or it may have been that some proportion of the male strobili were not viable. There is also the question of variability in the number or distribution of male flowers between branches on the same tree. Studies may be necessary to clarify these points, and future surveys should rely more on dissections rather than gross ocular observations to remove this source of error.

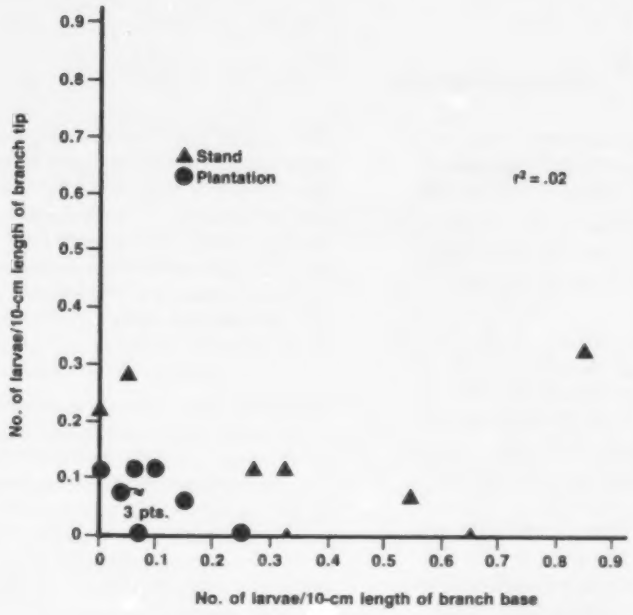

Figure 2. Relationship between number of overwintering L2 larvae on branch bases and branch tips.

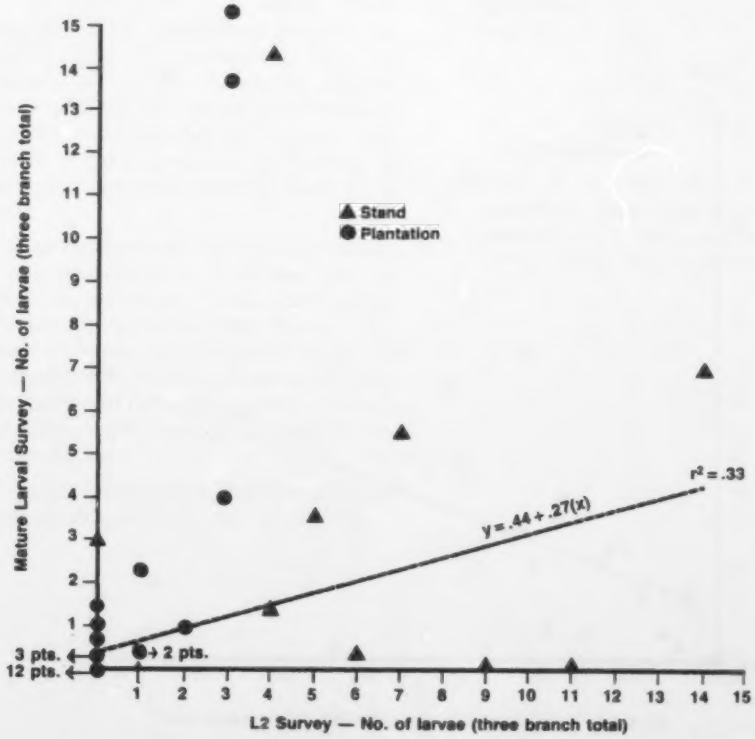

Figure 3. Relationship between overwintering L2 larvae and number of mature larvae the following summer.

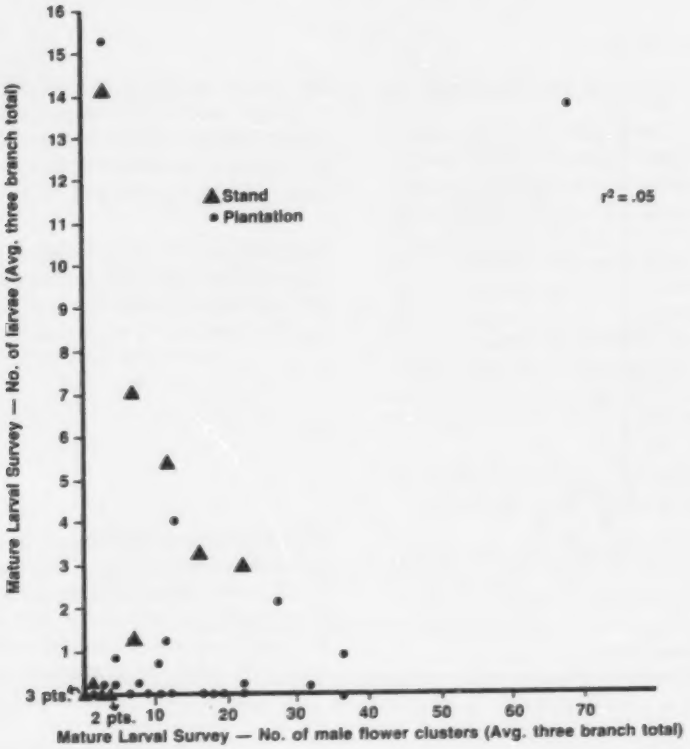
Mature Larval Survey — No. of larvae (Avg. three branch total)
Stand
Plantation
$r^2 = .05$
3 pts.
2 pts.
Mature Larval Survey — No. of male flower clusters (Avg. three branch total)

Figure 4. Relationship between number of mature larvae and number of male flower clusters.

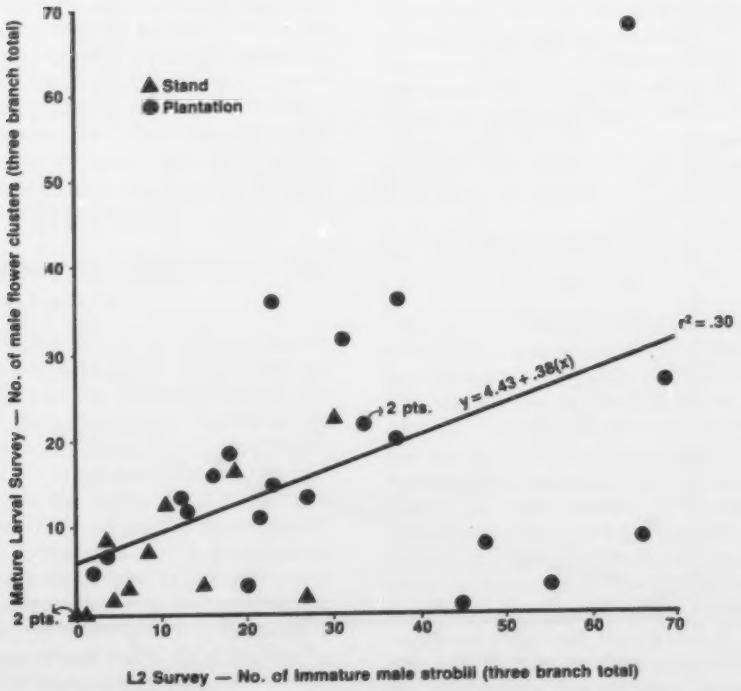
Mature Larval Survey — No. of male flower clusters (three branch total)
Stand
Plantation
$r^2 = .30$
$y = 4.43 + .38(x)$
2 pts.
2 pts.
L2 Survey — No. of immature male strobili (three branch total)

Figure 5. Relationship between predicted number of male flowers and number of male flower clusters the next summer.

Summary

This report outlines the process followed by the New Brunswick Department of Natural Resources to reach a "no control" decision for 1984 after the discovery of jack pine budworm defoliation in plantations and natural stands of jack pine the previous year. A **provisional** forecast table based on overwintering L2 larvae was derived using unconfirmed assumptions. Although a forecast of very low populations was correctly made, the validity of the table remains to be demonstrated for all levels of infestation.

Several minor studies were also conducted but resulted in very poor correlations presumably because of limited sample size and the fact that only very low infestation levels were encountered. Nevertheless, it is suspected that a significant number of L2 larvae of jack pine budworm overwinter on the basal portion of the branches (trunks were not examined) rather than on the 60-cm outer portions. Studies must be conducted to determine what is the appropriate branch sample length, and the proper number of branches per location to provide a reliable population estimate. Although mid-crown branches were selected in this study, this also needs to be verified as being the most representative part of the trees to sample.

The ability to predict the number of late instar larvae was also inhibited by the low numbers of insects that were encountered in both the L2 winter survey and the subsequent summer survey. Additional studies are needed to examine the full range of population levels. In addition, it would be beneficial to relate larval densities, especially at the overwintering L2 stage, to levels of defoliation that are subsequently caused the following summer.

Finally, the expected relationship between increasing larval densities with increases in male flower production was not evident in this study. It was speculated, however, that there might be some insect/flower density threshold beyond which this increase becomes evident. Further studies are therefore needed to clarify this situation and hence to determine whether some measure of predicted male flower production is essential or even beneficial.

In conclusion, it appears that these limited investigations raised more questions than they answered.

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Forest Protection Limited
1985 Program Report

by
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Forest Protection Limited
P.O. Box 1030
Fredericton, N.B. E3B 5C3
July 12, 1985

Areas Treated Operationally
Area Sprayed in Hectares and Acres, By Insecticide, Dosage, Application Rate, Carrier & Aircraft Type

Application	Hectares Thousands	Acres Thousands	Aircraft Type
One Application			
(a) 30 B.I.U./ha Dipel 132 Undiluted	78	192	TBM, M18, Ag Cat, Bell 206 Pawnee, Ag Truck
(b) 30 B.I.U./ha Thuricide 48LV - Undiluted	3	8	M18
	81	200	
Two Applications			
(a) 210 g/ha Fenitrothion in 1.46 ℓ/ha + 210 g/ha Fenitrothion in 1.46 ℓ/ha – Dowanal, Atlox 3409F and water.	165	408	TBM, M18, Ag Truck, Pawnee, Ag Cat, Bell 206
(b) 210 g/ha Fenitrothion in 1.46 ℓ/ha – Dowanal Atlox 3409F and water + 210 g/ha Fenitrothion in 1.46 ℓ/ha Cyclosol 63 and Oil	3	8	TBM
(c) 70 g/ha Matacil 180F in 1.46 ℓ/ha + 70 g/ha Matacil 180F in 1.46 ℓ/ha Atlox 3409F and water.	447	1,105	TBM, Ag Cat
(d) 70 g/ha Matacil 180F + 70 g/ha Matacil 180F – undiluted	5	11	Ag Truck
TOTAL	620	1,532	
GRAND TOTAL	701	1,732	

D. S. Henry
July 11, 1985

Owner	Area Sprayed by Ownership, by Application, by A/C Type – Hectares						
	T.B.M.			Light Spray A/C			
	Two App. Chem.	One App. Chem.	B.t.	Two App. Chem.	One App. Chem.	B.t.	
Dept. Natural Resources	375,345	—	—	155,474	—	76,848	
Fraser Inc.	54,412	—	—	5,191	—	—	
NBIP Ltd.	23,436	—	—	706	—	570	
Georgia-Pacific Corp.	—	—	3,719	—	—	—	
Boise Cascade Can. Ltd.	1,778	—	—	722	—	—	
Consol. Bathurst Inc.	2,191	—	—	150	—	—	
St. Anne Nackawic P&P	—	—	—	317	—	—	
TOTAL TBM	457,162	—	3,719	—	—	—	460,881 ha.
TOTAL LT. A/C	—	—	—	162,560	—	77,418	239,978 ha.
							700,859 ha.

D. S. Henry
July 12, 1985

General

At the meeting of the Board of Directors of Forest Protection Limited held on December 19, 1984 a forecast of 1985 insect populations and hazard was reviewed by DNR entomologists. Based on these forecasts it appeared that some 900,000 hectares should be sprayed in 1985 to prevent excessive defoliation by spruce budworm.

The meeting then unanimously "Resolved that the President be given authority after confirmation of the acreage to be sprayed for each sponsor to order the required insecticide and to contract the required aircraft for the 1985 project".

On December 20, 1984 a letter was forwarded to the Minister of Environment, Hon. C. W. Harmer requesting approval in principle for the purchase and use of materials for the following spray formulations:

(a) Fenitrothion + Dowanol + Atlox + Water

(b) Matacil 180F + Atlox + Water

(c) B.t. in registered formulations

In a letter dated January 15, 1985 approval in principle for the above formulations was received from Hon. C. W. Harmer.

In early January 1985 DNR personnel in cooperation with personnel from member companies and FPL began the precise definition of areas to be sprayed and proceeded to deliniate these areas for spray blocks with straight lines and two parallel sides. This procedure resulted in 101 spray blocks totalling 479,708 ha for TBM Avenger spray aircraft and 827 spray blocks totalling 299,826 ha for small agricultural type spray fixed wing aircraft and helicopters.

Concurrently operational planning was underway including negotiations with aircraft contractors, airport managers, material suppliers and former and potential employees with particular qualifications.

As suggested in the 1984 project report it was decided that in 1985 Forest Protection Limited would not subcontract spray areas as in 1984. Specifically spray aircraft contracts would be fore aircraft, their maintenance and pilots only. Forest Protection Limited would provide, control and supervise navigators and navigation aircraft, airstrips, mixing and loading, board and lodging and would dictate movement of spray aircraft from one airstrip to another ensuring flexibility and providing for maximum utilization.

Sponsors confirmation of areas to be sprayed were completed on February 15, 1985 with the receipt of DNR commitments. Total areas confirmed by all sponsors were as follows:

To be sprayed by	Chemical	B.t.	Total
TBM Avengers	475,989 ha	3,719 ha	479,708 ha
Small Ag-Type	210,752 ha	89,074 ha	299,826 ha
	686,741 ha	92,793 ha	779,534 ha

Based on the proposed areas as confirmed by the sponsors a budget of $9,563,000 for the 1985 fiscal year was approved by the Board of Directors at the meeting held on April 1, 1985. This approved amount included the costs for overhead, surveys, and R&D along with the costs of insecticides and application.

On February 18, 1985 purchase orders were issued to the low bidders for some 90 per cent of our expected insecticide requirements. Some sponsors had indicated that small reductions in areas to be sprayed might result from further area examination and the results of L2 surveys which were still in progress. Insecticide suppliers had indicated that small increases in purchase amounts could be accommodated for some time yet but could not be guaranteed. However, there appeared to be enough competition from other suppliers that there was little risk in holding back ordering a small part of our requirements.

Purchase orders for insecticides issued on February 18, 1985 were as follows:

(a) To Sumitomo Canada Limited, the low bidder for fenitrothion — 48,000 kg (105,821 lbs) of Sumithion @ $8.36/kg ($3.80/lb)

(b) To Chemagro Limited, the sole supplier of Matacil — 300,763 litres (about 80,000 US gal) of Matacil 180F @ $4.77/litre ($26.50/kg Aminocarb — $12.02/lb)

(c) To Abbott Laboratories, Limited, the low bidder for B.t. — 190,000 litres (50,198 US gal) of Dipel 132 @ $4.37/litre ($0.344/B.I.U.).

All above dollars are Canadian funds.

Subsequently, on April 2, 1985, further purchase orders were issued at the above same prices as follows:

To Chemagro Limited — 21,000 litres of Matacil 180F

To Abbott Laboratories, Limited — 25,000 litres of Dipel 132.

On April 3, 1985, a formal application for a spray permit along with a letter of explanation and detailed maps of areas requested for treatment addressed to Hon. C. W. Harmer were delivered to the Department of Environment. This application for a spray permit was for an area of 737,000 hectares reflecting changes made by sponsors primarily based on results of further L2 surveys.

On May 9, 1985 Hon. Malcolm MacLeod signed a letter of agreement to implement Order-in-Council

#85-357 which authorized Forest Protection Limited to carry out the spray program as specified.

Permit No. P20 signed by Hon. C. W. Harmer was received on May 17, 1985. This permit authorized the use on specific areas of the formulations already given approval in principle.

During April and early May, DNR personnel carried out an aerial inspection in aircraft provided by FPL of all small areas proposed for treatment to verify forest types and note harvesting that had taken place since photography was carried out as well as the establishment of permanent residences or other pertinent details. This inspection resulted in considerable area reduction.

Through April and May mixing and loading facilities were set up on the following airstrips:

For TBM Avenger Spray Aircraft	
Boston Brook	
Brockway	
Sevogle	
For Agricultural Type Spray Aircraft	
Bathurst	Grafton
Boston Brook	Moncton
Brockway	Sevogle
Charlo	Sisson Ridge
Chipman	St. Quentin
Dunphy	Weyman

In addition, mobile tankers for insecticides and fuel were arranged for loading two helicopter units. These spray helicopters worked from various gravel pits, side roads, etc. wherever most convenient to keep ferry distances to a minimum.

Complete living facilities were established at Boston Brook, Brockway, Chipman, Dunphy and Sevogle. Arrangements were made for personnel working at other airstrips or with the helicopter units to live and eat at the most convenient motels and restaurants.

A fleet of spray and navigation aircraft was assembled for the project made up as shown on page 9.

Training of pilots and navigators was carried out at Chipman and Brockway. In addition to the two Bell 47 helicopters for navigation of the Bell 206 spray helicopters, three small Robinson 22 helicopters were contracted for the first time for navigation of three teams of ag-type fixed wing spray aircraft.

On the advice of Mr. Lester Hartling, DNR entomologist, that in certain areas both insects and foliage had developed to the appropriate stage spraying was commenced from Grafton, Chipman and Weyman on the evening of May 26. This was later than normal for such development — simply stated it was a late cold spring.

Although other areas were ready for spraying shortly after, biological development continued to be erratic and late, and unfavorable weather patterns hampered spraying for much of the season. The department of Natural Resources assessment report to be published later will undoubtably treat this matter in considerable detail.

The second application on blocks scheduled for chemical treatment was completed on June 21 with aircraft working from Bathurst, Boston Brook and Sevogle. At this date, there still remained considerable area in southern N.B. scheduled for B.t. treatment.

For the next several days marginal weather allowed only sporadic spraying and low productivity.

On the morning of June 26 spray operations were terminated on the advice of DNR entomologists that the insect had reached such a stage that further spraying would accomplish little in preventing defoliation. Some nine thousand hectares scheduled for B.t. spraying in the Moncton area were left untreated. Except for these nine thousand hectares all other areas were treated according to plan.

An Information Centre was operated in the Forest Protection Limited office in Lincoln, as announced by public notice in New Brunswick newspapers. A toll-free service was available from any part of the Province for those requesting information. This service was in operation daily from 5 a.m. to 10 p.m. during the project period. The Information Centre personnel were fluent in both official languages. Their duties included answering all calls in a factual manner and arranging for call-backs if the requested information was not readily available.

In addition, information in both English and French as to areas for spraying in the next 24 hours was sent daily by ENVOY 100 for distribution via the New Brunswick Information Service closed circuit teletype. This same information was also made available by a toll-free Code-a-Phone service on a 24 hours-a-day basis.

Results of 1985 Program and Forecasts for 1986

The Department of Natural Resources is currently carrying out surveys to assess the success or otherwise of the 1985 spray project. Also surveys will continue to be carried out as a basis for predicting 1986 populations and hazard. Analysis of these surveys will be available this autumn.

Forest Fires

Forest Protection Limited aircraft were not required for forest fire control this spring.

Status of Legal Matters

No legal actions were outstanding as of July 12, 1985.

Program Costs

Precise costs cannot be determined until the end of our fiscal year, October 31, 1985, and the audit has been completed. However, at this date it appears that our authorized budget has been respected.

W. J. Irving
July 12, 1985

1985 Aircraft Fleet

Aircraft Type	FPL Owned FPL Operated FPL Controlled	Dry Leased FPL Operated FPL Controlled	Contracted FPL Controlled	Total
Spray Aircraft				
TBM Avenger	12	—	—	12
Ag-Cat	—	—	8	8
Cessna 188	2	—	6	8
M-18	—	—	4	4
Pawnee	—	—	2	2
Bell 206	—	—	4	4
Total Spray	14	—	24	38
NonSpray Aircraft				
Cessna 185	—	3	—	3
Cessna 172	—	28	—	28
Robinnson 22	—	—	3	3
Bell 206 (Rescue)	—	—	1	1
Bell 47	—	—	2	2
Total NonSpray	—	31	6	37

38 Spray Aircraft + 37 non spray aircraft = 75 Total

Insecticide

Insecticide Utilization

The following table is a summary of Forest Protection Limited's utilization of insecticide in 1985. The information below is given in liters.

Insecticide	On Hand Nov. 1/84	Purchased in 1985	Sold	Used in 1985	On Hand June 30/85
Fenitrothion	24,628	37,924	-0-	50,660	11,892
Matacil 180F	32,894	323,832	1,022	334,559	21,145
Dipel	4,000	214,075	1,843	194,505	21,727
Thuricide 48LV	6,800	-0-	200	6,600	-0-

Formulations

The formulations applied by Forest Protection Limited in 1985 were as follows:

Fenitrothion (Water Based)
210 g/A.I. in 1.46 ℓ/ha
(3 oz A.I. in 20 U.S. fl. oz./ac)

Matacil (Water Based)
70 g A.I. in 1.46 ℓ/ha
(1 oz A.I. in 20 U.S. fl. oz/ac)

B.t. Thuricide 48LV and Dipel 132
30 BIU/ha (12 BIU/ac)

Research and Development

The following summary of 1985 Research and Development work includes a brief listing of major research areas as well as a comment on the objectives of individual projects within each area.

Navigation

FPL has been actively searching for an electronic navigation system capable of improving our current navigational abilities since 1979. In 1985, a Loran C unit, supplied by Internav, was tested by FPL personnel. Results from the 1985 test are not yet available.

Spray Targeting Trials

This trial investigated the effect of helicopter rotor wake on spray deposit. It was postulated that the force of the rotor downwash, at a low airspeed, should improve the amount of spray deposited on foliage.

Spray Drift Measurement

The New Brunswick Department of Health funded a study whereby air samples were collected at different heights and distances downwind from operational spray blocks. These samples are currently being analyzed. The study is intended to provide an indication of airborne spray drift. FPL supplied the aircraft and pilot required for this project.

Efficacy Tests — Biological Insecticide

Three tests were conducted, using Bacillus thuringiensis (Bt). two of which involved testing new BT formulations, the third being a continuation of a 1984 study into the effects of concentration of BT on efficacy. Formulation tests included assessment of a Futura formulation and Dipel formulations. Dipel formulations were applied to blocks 95-98 inclusive. Futura was applied to the Northern two thirds of block 197 and all of block 193. The third study was a cooperative study funded by FPL, CFS, Province of Quebec and Zoecon Industries Ltd. and conducted by CFS and RPC, and had the following objectives:

(1) relating foliar deposit of Bt to field efficacy, applied at three concentrations of 30 BIU/ha.

(2) determining the dose/response relationships of the concentrations.

(3) determining the effect of weathering at the three concentrations.

(4) determining the usefulness of samarium (a rare earth element) as a tracer.

Efficacy Tests — Other Biological

Field tests of spruce budworm phermone and Trichogramma minutum, a parasitic wasp, will be conducted after the 1985 larval spray program.

Efficacy Tests — Chemical Insecticides

In 1984, FPL initiated field testing of Matacil and fenitrothion applied at low volumes (approximately 0.15ℓ/ha). On the basis of the 1984 results, Matacil has been granted a temporary registration at this application rate. The trials have been repeated in 1985, with Matacil being applied semi-operationally and fenitrothion being applied to smaller experimental areas. One other efficacy trial was conducted using Sumithion 20F formulation at the conventional application rate of 0.6ℓ/ha. Low volume Matacil application was completed on operational blocks 81-84, 89-91, 189-192, 199, 222. Low volume fenitrothion was completed on blocks 232-234.

Environment Impact Studies

FPL provided the aircraft for a test that was to determine the effect of Zectran (a chemical insecticide) on terrestrial and aquatic ecosystems. The study was conducted jointly by the Canadian Wildlife Service and Forest Pest Management Institute.

Atomizser Testing

FPL continued to support Dr. Picot's work at UNB aimed at finding spray atomisers capable of producing a droplet spectra measuring less than 55 microns.

Lapse Rate Determination

Temperature profiles, from near canopy to several hundred feet above ground level, were collected by senior pointers using sensitive electronic thermometers. These profiles are important in determining the atmospheric stability above treatment areas, which in turn is an important consideration in defining "spray weather." If these thermometers prove to be useable and accurate, they will be included in future programs on a larger scale.

Review of Records

A study was carried out to ascertain if existing records would confirm or negate the hypothesis of SERG scientists that early, clear-morning spraying is least productive since it is associated with low level inversions.

The resulting examination indicated that the available records are not adequate to either confirm or reject the hypothesis.

Communications

This project tested the ability of the Envoy 100 communications system to streamline inter-airbase communications. Portable data-terminals were issued to each mobile and fixed base. Final costs and assessments are forthcoming.

Results of 1985 R & D projects are not available at date of writing. Reports will be made available as soon as they are complete.

C. A. Howard
July 12, 1985

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Spray Technology

by
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The New Brunswick Research & Productivity Council is a contract research organization which, for several years, has been part of the New Brunswick Spray Efficacy Research Group, a group which has mainly, if not solely, been concerned with aerial spray application research for the control of spruce budworm.

Working alongside Forest Protection Ltd., the National Research Council, University of New Brunswick and CFS-Maritimes, information has been obtained and applied to make aerial spray operations more effective. As more research is done and more information becomes available, technology transfer to spray operators will continue.

Almost all of the research is carried out with a view toward operational sprays. For example, a series of experiments into the effects of atmospheric stability on spray deposition up to 400 m downwind of the spray line and spray drift up to 1200 m downwind of the spray line was conducted at the Dunphy test site from 1982 through 1984 and will hopefully be concluded this year.

Concepts

The ultimate objective of any spray operation is to provide good foliage protection. In order to be effective the budworm must come into contact with the pesticide at a susceptible stage of its life cycle. For a chemical insecticide such as Matacil or Fenitrothion, this means primarily dermal contact with the budworm larvae whilst for **B.t.** "contact", requires actual ingestion of the deposit.

The chance of a budworm larva coming into contact with a deposited droplet of insecticide depends upon several factors, one of which is how much it moves in and around its microhabitat whilst feeding, spinning new silks or removing frass. I.W. Varty at MFRC has been testing the hypothesis that this movement is affected by post-spray weather. He has shown that larval activity was stimulated by warm, dry, calm weather and inhibited by cold, wet, windy weather. Post-spray weather conditions which are condusive to movement of the larvae in and around the microhabitat cannot be guaranteed, particularly since, at this stage, there is not sufficient confidence in weather forecasting to let a spraying opportunity slip by for fear of poor weather in the days to come. In other words, a more definite and reliable means of increasing the chances of the larvae coming into contact with the insecticide must be found. This can be done by obtaining the best deposit possible (for a given amount of insecticide) in and around the budworm microhabitat.

Spray deposition is influenced by many physical factors, e.g. humidity atmospheric, stability, wind speed and turbulence, canopy density and flying height, only a few of these are under the control of the applicator, but one important parameter which can be controlled is droplet size through choice of atomizer. The optimum droplet size for protection of fir and spruce foliage (from a droplet capture point of view) has been determined by Jules Picot and Dave Kristmanson at UNB to be between 15 and 55 um, obviously the best atomizer for any particular formulation will be the one which produces the highest volume flow in the evaporated droplet sizes of 15-55 um at the flow rate adequate for the particular application. If more than one formulation is being sprayed it may well be necessary to periodically change the parameters under which a given atomizer type is operating or even use different atomizers in order to achieve this.

Deposit Assessment

To date, the best parameter with which to correlate spray efficacy is deposit on the needles, buds and silks of the microhabitat. Deposit on kromecote cards bear no relation to deposit in the pest habitat. At best, it gives some measure of what was not deposited on the foliage and that the aircraft was emitting spray when it passed overhead! If it is necessary to use artificial targets, then at least they should have similar aerodynamic properties as the intended target surface. The best sampling unit is to use the actual target itself for deposit assessment.

This year (1985), as in the past, RPC has evaluated both quantitatively and qualitatively the deposits obtained from several spray trials with new formula-

tions and from operational sprays. Chemical insecticide deposits were measured quantitatively on twigs by gas chromatography with samples being analysed either individually or bulked. **B.t.** deposits were assessed using microscopic analysis. In order to do this, non-insecticidal dyes are incorporated into the formulation enabling droplets deposited on the needles to be measured and counted. Droplet measurements of chemical insecticide can be done similarly although problems do occur with oil based formulations — the deposits soak into the needle surface and are difficult to measure. All qualitative measurements must be adjusted in the applicable spread factors. This year, approximately 120 man weeks were spent counting droplets and around 1,000 quantitative deposit assessments made by GC analysis. We are currently developing a bioassay technique to quantitatively determine **B.t.** deposits on foliage, this quick, accurate technique will be very useful in the future.

Deposit data are correlated with pre and post spray larval counts and defoliation levels as assessed by Ed Kettela at MFRC. To rigorously compare two insecticide applications it is absolutely essential to measure actual deposit on foliage. e.g., we have observed a ten fold difference in deposit levels between two sprays made at the same time, on blocks less than five miles apart, with identical aircraft, spraying formulations with identical atomization characteristics. To have drawn accurate conclusions from the results of these two sprays without making any assessment of deposit would have been meaningless.

If the decision is made to institute a forest protection programme in Manitoba there is a wealth of expertise in New Brunswick which can be consulted for the design, implementation and evaluation of such a programme. RPC will be pleased and eager to be involved and provide any services which may be required.

Jack Pine Budworm Information Exchange

I Control Workshop

The following issues were discussed as they pertain to the control of jack pine budworm populations:

1) Status of Registered Control Products

Three formulations of fenitrothion are registered in Canada for control of JPBW. In 1985, temporary registration was granted to the Bt products Dipel and Thuricide. Data from the spray operations in 1985 will determine full registration of the products. Matacil and fenitrothion (new rate) will also receive full or temporary registration in 1986. Generally agreed more field data is needed for all products being registered to control JPBW.

2) Is Control Cost Effective

When selecting jack pine stands for treatment, there is a long list of criteria to follow, eg. harvesting schedule, high value stands (planted, thinned, etc.) and market potential. To assist decision making, more impact studies and data are needed. Herb Cerezke (CFS-NoFC), Jan Volney (CFS-NoFC), Gary Simmons (Mich. State Univ.) and Gordon Howse (CFS-GLFC) were nominated to gether regional JPBW information, pool data on history of outbreaks in Central Canada/ U.S.A. and pool existing data on impact studies. A standard method of collecting current impact plots is needed and Herb Cerezke, Gary Simmons and/or Jan Volney were asked to communicate on this subject.

3) Type of Control to Take

The +ve and –ve aspects of chemical and biological control was discussed. All agreed chemicals should be kept as a tool of control for a) back-up, if problems should arise with Bt., b) an instant knock-down and c) a control option. It was recommended the pooling of regional and impact studies should include results of silvicultural control activities. Status of other biological controls, eg. pheromones, viruses, parasites is uncertain but research into these areas should be encouraged. A hazard rating system should be developed from the results of current impact studies. Al Jones (Minn. Nat. Res.), Jan Volney (CFS-NoFC), Joe Meating (CFS-GLFC) and Bob Ford (USDA-St. Paul) will communicate on the findings of their impact study plots. Al Jones will organize, pool and distribute the results.

4) Timing of Control (Spraying)

Using both larval instar and shoot development as indicators to spray was unreliable. Manitoba and Ontario agreed to look at shoot vs. larval development in 1986. The amount of spray deposit on pine needles at different shoot development stages was also questioned. Chris Riley (RPC) agreed to examine this aspect during Bt aerial spray trials in 1986.

Control Workshop Recommendations:

a) need more impact studies

b) pool existing impact and silvicultural data with regional and historical information

c) keep chemicals as a tool of control

d) encourage more research into biological control options

e) develop a hazard rating system from new and current impact data

f) determine timing for control spraying

II Survey Workshop Recommendations

The Survey Workshop discussed the following issues as they pertain to jack pine budworm population monitoring:

1) Sampling Procedures

Due to the variation and unreliability of current techniques, it was recommended that a group of cooperators be established to work towards developing effective sampling systems including: egg mass survey, flower bud production, L_2 survey, larval surveys and defoliation assessments. Attempts would be made to standardize sampling techniques, however, regional differences may prevent a complete standardization

2) Staminate Flowers

The importance of male flowering to larval survival was recognized. The ability of larvae to survive in the absence of flowers needs to be further researched. Flower production should be included in prediction surveys.

3) Role of Parasitism

It is necessary to determine the impact of parasitism and predation on budworm populations. This information could be useful when considering silvicultural or other controls different from the conventional insecticide application. It was suggested by V. Nealis that assessing per cent parasitism in operational surveys would be too laborious and time consuming.

4) Role of Stress

Increases in staminate flower production have been observed following drought conditions, while a decrease in flowering seems to occur following severe defoliation. It was suggested that data collected by tree improvement specialists may provide information on what conditions induce or reduce flowering.

5) Impact Information

It was agreed that growth loss and top-kill have a substantial impact on stand volume. This impact has often been downplayed. Current research by J. Volney is assessing impact in relation to stand density, age class, site class and species composition. A recommendation was made to establish a C.I.F. entomology-pathology working group to lobby for more impact studies.

6) Role of Pheromones

The usefulness of pheromones in monitoring endemic populations was recognized. It was recommended that the Research Productivity Council be given financial support, through the federal-provincial agreements, to develop a satisfactory lure for jack pine budworm.

Although John Dixon was unable to attend the workshop, he has offered to make two of his papers: *Jack Pine Budworm Surveys* and *Report on Project to Develop a Survey Manual for Jack Pine Budworm* available to any of the participants. His address is included in the following invitation list.

Appendix I

Jack Pine Budworm Workshop

Invitation List

Attendee List — Bold

ALLEN, Dr. Doug
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